Fires

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Background to Fire Disasters

Relative Importance of the Problem

Historically, the United States has had a tremendous public health problem associated with fires. Currently, the problem is still of major concern, although its complexity and nature have evolved over time. Contemporary catastrophic fires should be viewed as an unnecessary and preventable problem that certainly deserves the greater attention and efforts of public health professionals.

Each year in the United States, fires result in approximately 5,000 deaths and 300,000 injuries that call for medical treatment (1). Many of these nonfatal injuries require prolonged hospitalization and extensive surgical and medical care. According to some sources, fire disasters cause more loss of life and property damage than all types of natural disasters combined (2).

Unlike many other public health situations, fires are a worse problem in the United States than in other developed countries. Crude fire-associated mortality rates show that the relative risk for persons in the United States is 2-3 times greater (Table 1) than for persons in many other countries. Although these crude rates are not adjusted for population differences with respect to such crucial characteristics as age and sex, the importance of this problem for the United States (and Canada) is certainly clear.

As one type of injury, burn injuries are the second most frequent cause of death in the home, preceded only by falls (3). Burn injuries result in more catastrophic adult fatalities than any other cause (4). In the United States the annual number of adult burn injuries has been estimated at 1 million (5). Estimates of adult rates for burn injuries requiring hospitalization range from 26 to 37 burn injuries/100,000 adults (6-10). With respect to number of years lost by death from specific causes (11), the prevention of a single burn injury fatality results in a greater savings of life than the prevention of death from cancer or cardiovascular disease (12). As shown in Table 1, the fire-associated mortality rate in the United States in 1974 was 2 9 deaths/100,000 persons. This rate has decreased from approximately 4.0 in the 1950s and 1960s (Figure 1). After 1974, the rate increased, and then decreased again to reach a level of approximately 2.3.

Medical Implications of Burn Injuries

One of the most serious insults the human body can experience is a fire-associated burn wound. Burn injuries that require hospitalization are both serious and costly (13). They require more bed-days/patient than any other type of injury (7,14). Furthermore, severe burn injuries are one of the most difficult problems in medicine to treat (12). Patients with burns may need extensive hospitalization with multiple surgical procedures and may be left with lifelong disfigurement and deformity. Severe burn injuries subject both the patient and family to profound psychological and financial stress (15).

The greatest gross effect of burn injuries is the alteration of body-surface appearance. In contrast, the greatest medical impact is the local and systemic physiologic changes. The extent of damage is influenced by many histologic factors. Tissue conductivity greatly affects the absorption rate of thermal energy. Nerves and blood vessels conduct thermal energy at the greatest rate, whereas bone is the tissue most resistant to thermal exchange (16). Connective tissue and muscle conduct energy at intermediate rates (17). A second histologic factor influencing the rate of absorption or dissipation of thermal energy is peripheral circulation (17).

Estimating the extent of a burn injury is necessary for initial triage, for prognosis of long-term morbidity and mortality, and for research purposes. The extent of a burn injury is usually quantitatively expressed as the amount of surface area injured in relation to the total body-surface area. To aid in the estimation of the extent of burn injuries, Berkow first described, in 1924, the percentage of area represented by various body segments (18). These percentages were later modified by Lund and Browder (19) to adjust for age, since the head and neck area of a child constitutes a larger percentage of body-surface area than does that of an adult. A method for quickly determining the body-surface area burned is the "Rule of Nines," devised by Marshall (20). When estimating the total extent of a burn injury, areas with first-degree burns are usually not included (21).

The major pathophysiologic effects of burn injuries involve the cardiovascular system. Burn injuries cause damage to the endothelium, the smaller inner lining of the vessels, which leads to thrombosis. Burn injuries result in dramatic alterations in cardiac function (22). An initial drop in cardiac output occurs, which with extensive burn injuries (> 50% of total body-surface area) approaches 30% of preburn values (23). Cardiac output usually returns to normal values within 36 hours after injury (24,25).

Immediately after a burn injury, capillary permeability in the wound area increases markedly and results in the loss of fluid from the intravascular compartment into the extravascular, extracellular space (26,27). Besides fluid, tremendous amounts of protein (globulin and albumin) are lost into the extravascular space (28-30). Serum leakage through the injured microcirculation results in severe disturbances of body water, electrolytes, serum proteins, and metabolic substrates (31-33). The loss of nutrients through the wound causes a negative nitrogen balance, which contributes to weakness and weight loss (34).

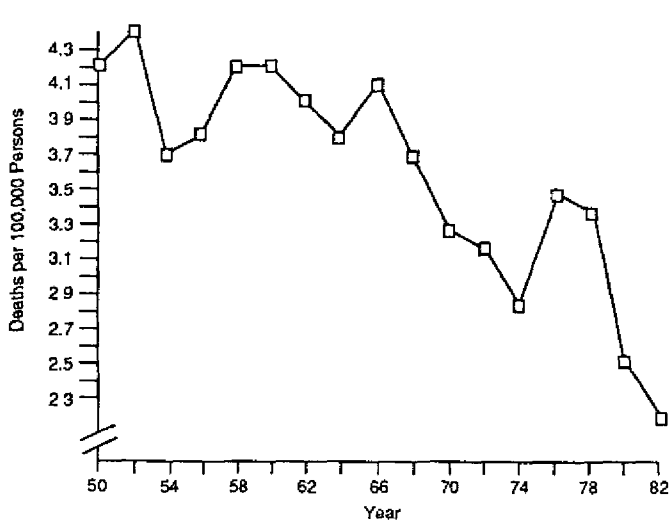
The pathophysiologic changes of burn injuries also involve the pulmonary system. Increased ventilation is usually present and directly proportional to the magnitude of injury (35). With burns of ≥ 40% of total body-surface area, most persons have restrictive pulmonary disease characterized by decreased vital capacity and increased pulmonary resistance. Pulmonary function is greatly affected by concomitant injury caused by toxic combustion products (36-38).

TABLE 1. Fire-associated mortality rates per 100,000 population, by country, 1974

COUNTRY	RATE
Canada	3.6
United States	2.9
Sweden	1.6
Japan	1.5
United Kingdom	1.5
France	1.5
Australia	1.5
West Germany	0.9
Switzerland	0.7

Source: Reference 1

FIGURE 1. Fire-associated mortality rates, by year, United States, 1950-1982



Source: Reference 1

Historical Perspective on Fire Disasters

Fire disasters can be attributed to extremely varied causes. They may accompany natural disasters such as earthquakes and volcanic eruptions. Sources of ignition for fire disasters have included lightning, human carelessness, arson, and malfunctioning equipment. These disasters have occurred above the ground (in tall buildings and on planes), on the ground, and below the ground (in mines and caves). Sometimes they occur in circumstances that are unexpected or unpredictable. For example, several fire disasters have involved the spraying of flaming liquids into crowds; in 1955, this scenario resulted in the deaths of 80 people who were watching the LeMans Grand Prix race. The mixture of causal patterns has varied with time, and one can hardly say that contemporary America has the same risks that it had 30, 50, or 100 years ago. A basic understanding of how these risks have changed assists in identifying preventive measures that have apparently been efficacious in the past or may need to be assessed in the future.

Seven descriptive categories of fire disasters, along with selected examples, are shown in Table 2 (39). The first category pertains to disasters resulting from forest fires. The three examples provided occurred either before or during the early 1900s and involved three different states. During this period, information dissemination and warning systems along with fire fighting and control capabilities did not compare with those available today. These types of disasters have evolved to the point that they have far greater impact on the environment than on the public health of surrounding communities. Each year such fires destroy thousands of acres of valuable grass and timberland, while their impact on morbidity and mortality is minimal. Examples of this modified impact of forest fires include the 1947 Maine fire (16 deaths; 1,200 structures damaged; and 206,000 acres [83,400 hectares] of timber and scenic forest destroyed); the 1964 Cayote, California, fire (one death; 188 structures damaged; and 175,000 acres of watershed land destroyed); and the 1977 Santa Barbara, California, fire (no deaths, but 250 structures damaged, along with 800 acres of watershed land destroyed).

Tangentially related but basically different are fire storms—both naturally occurring and human generated. These natural storms develop from forest fires. They result in a convection plume consisting of hot gases that cause air to be drawn inward at the base. This wind then begins to rotate and forms a fire-induced cyclone that, like a tornado, has counterclockwise winds in the Northern Hemisphere. Apparently, the worst natural fire storm occurred at Peshtigo, Wisconsin, in 1871. It burned over 2,000 miles^2 (5,180 km^2) of forest and killed approximately 2,300 people. Near Sundance, Ohio, in 1967, a fire storm had surface winds of 50 mph (80 km/hour), peak winds of 120 mph; it lasted for 9 hours. This fire storm destroyed 70 miles^2 of land However, the incidence of natural fire storms is low enough that the adverse public health impact is small.

Human-generated fire storms resulted from incendiary bombing during World War II. In Hamburg, Germany, on February 27, 1943, the Allied Air Forces dropped bombs that caused a fire storm with winds up to 100 mph, destroyed 3.2 miles^2 of city, and killed 21,000 residents. In Dresden, Germany, on February 13-14, 1945, bombs induced a fire storm that had surface winds up to 80 mph, burned 4.6 miles^2 of

TABLE 2. Selected fire disasters, by category, date, and associated mortality, United States

Category	Date	Number of fatalities
Forests:		
Michigan and Wisconsin	1871	1,000
Minnesota	1894	894
Minnesota and Wisconsin	1918	1,000
Cities:		
Chicago	1871	766
Peshtigo, Wisconsin	1871	800
San Francisco	1906	1,188
Chelsea, Massachusetts	1908	18
Ships:		
New York harbor	1904	1,000
Rhode Island coast	1954	103
Hotels:		
Winecoff (Atlanta)	1946	119
LaSalle (Chicago)	1946	61
MGM Grand (Las Vegas)	1980	84
Hilton (Las Vegas)	1980	8
Stouffers Inn (New York)	1981	26
Places of entertainment:		
Theater (Chicago)	1903	602
Dance Hall (Mississippi)	1940	207
Nightclub (Massachusetts)	1942	492
Circus (Connecticut)	1944	163
Supper Club (Kentucky)	1977	164
Health-Care Facilities:		
Hospital (Oklahoma)	1918	38
Nursing home (Missouri)	1957	72
Hospital (Connecticut)	1961	16
Nursing home (Ohio)	1963	63
Nursing home (Ohio)	1970	31
Schools:		
Collinwood, Ohio	1908	161
Chicago, Illinois	1958	93

Source References 1,39.

city, and killed 135,000 persons. On March 20, 1945, an incendiary attack on Tokyo resulted in a fire storm that killed 84,000 persons.

Like forest-fire disasters, U S. citywide conflagrations were most devastating before or during the early 1900s. The sources of ignition for this type of fire disaster were both human generated (Chicago fire) and natural (San Francisco fire). The source of combustion was frequently wooden structures crowded on small land-surface areas. The contemporary risk of this category of fire disaster has been minimized by the development and enforcement of building codes, promulgation of standards to ensure the compatibility of all fire equipment with water supplies, and the regulation of building construction with respect to combustible materials.

Regarding the last category, considerable effort has been expended in the design and construction of "fireproof" buildings. Progress has been due in part to the evaluation of unsuccessful approaches. For example, when the Crystal Palace was built in Manhattan in 1853, it was considered to be fireproof since its frame was iron and its walls and roof were glass. Although iron and glass are not combustible, the contents of this building were. In 1858, a fire that began in the interior caused the entire building to collapse. The heat from the fire melted the crucial iron structural supports. The lesson learned from this incident was to have concern for combustible materials within buildings and to insulate structural steel so that it can not reach its 500 C melting point.

The third category of historical fire disasters consists of places in which groups of healthy persons reside on a temporary basis, for example, on ships and in hotels. In recent times, building codes have increased safety in such places by establishing criteria for interior passages, stairwells, and exits. These criteria are designed to prevent passageways and stairwells from becoming chimneys or disseminators for fires and to ensure that people have ample means of escape. Public health problems can result when these codes are not followed. In the United States from 1934 to 1961, 130 hotel fires killed 1,204 people (1). In November 1984, the Las Vegas MGM Grand Hotel fire killed 84 people. Investigation of this disaster showed that three of the four stairwells and their access panels did not comply with codes for 2-hour fire-rated construction (1). The fire and products of combustion that killed people spread through these stairwells.

Places of entertainment present special problems for the enforcement of fire codes. In such locations, large numbers of persons are crowded into unfamiliar and enclosed spaces. Either the exits (malfunction or inadequate number) or the furnishings and decorations (large quantities of flammable materials) may be problems. Perhaps the most famous fire disaster in this category was the Coconut Grove nightclub fire in Boston in November 1942. In this incident, most exits were either locked or they malfunctioned. Approximately half of the crowd—492 persons—died, and many others sustained serious burns.

For the most part, the potential for fire disasters in places in which people temporarily reside or seek entertainment involves the exposure of persons who have unimpaired physical and mental capabilities. Locations such as health-care facilities and schools, in which the exposed populations depend upon the providers for safety and well-being, are associated with even higher risks. These risks appear to be reduced when the occupied buildings are designed for the specific purposes intended, evacuation plans are developed and practiced, and engineering controls (e.g., fire doors and sprinklers) are present.

Epidemiology of Fire Disasters

Working Case Definition

The literature suggests many criteria for defining disasters. Some of these include cause, duration of occurrence, extent of damage, and number of casualties. With respect to the last criterion, suggested quantitative values are often provided. For example, one source (40) states that for an incident to be classified as a disaster, it must cause at least 25-100 casualties (injuries and deaths). However, agencies such as the Metropolitan Life Insurance Company (MLIC) and the Occupational Safety and Health Administration (OSHA) consider a catastrophe (disaster) to be an event that causes at least five casualties—either deaths (MLIC) or deaths plus hospitalizations (OSHA). This small number of victims from a single event is probably not perceived to be a disaster by many public health professionals. However, it is essential—both for the review contained in this chapter and the future prevention of fire disasters—that the definition of fire disaster include situations with only a few fatalities.

There are very few studies focusing on the epidemiology of fire disasters. Salient characteristics of selected, representative studies pertaining to burn injuries are shown in Table 3 (41-49). All of these investigations have been cross-sectional studies, and all but three are hospital-based case series. Consequently, they focus upon the more severe burn injuries. The number of cases per report ranges from 100 to 2,927. Two important trends are demonstrated in these reports. First, all but two of the studies are historical reviews and depend on data from medical records. Investigations of this kind are limited in types of variables that can be examined. Second, and more importantly, none of these authors distinguished between cases that did and did not result from disasters. Therefore, most available descriptive information about fire disasters is limited to surveillance statistics maintained by agencies such as MLIC and the National Fire Protection Agency (NFPA).

If the MLIC definition of disaster is used, fires represent the largest source of disasters in the United States (2). The NFPA appears to evaluate fire disasters by examining multiple-death fires that involve at least three fatalities. NFPA data demonstrate the public health importance of these events. In 1983, in the United States, 2,326,500 fires resulted in 5,978 deaths. Multiple-death fires accounted for only 0.01% of all fires but led to 16.4% of all fire-associated deaths (50).

Although distinguishing between definitions based upon events resulting in at least three deaths versus at least five deaths may appear trivial, it is important from a public health perspective. NFPA data shown in Table 4 indicate that in the United States in 1980-1984, 1,391 fire disasters (at least three deaths) caused 5,639 deaths, or an average of 4.1 deaths/incident. For each year in this 5-year period, the average number of deaths/incident was less than five. More extensive analysis shows that approximately 80% of these incidents each led to three or four deaths (Table 5). Fires that caused at least 10 fatalities represented only 1.9% of the multiple-death fires. Any definition of and research on fire disasters that focus on incidents involving at least 10 deaths—or even at least five deaths—fails to include the vast majority of events that impact mortality and represent the greatest public health risk. Therefore, the working definition of a fire disaster in this chapter is any fire that causes at least three deaths.

Severity of Injury: Implications for Mortality and Morbidity

Public health professionals should not equate the **severity** with the **extent** of injury from a fire disaster. The extent of a burn injury is denoted by the total area of body surface that sustained second- or third-degree burns. In contrast, the severity is determined not only by the extent of injury but also by anatomic location, age, physical condition, presence of preexisting disease, and presence of concomitant injuries (51). In addition, after adjustment for confounding factors, length of hospital stay has been used as an approximation for severity of some burn injuries (52-56).

For various critical anatomical areas of the body, burn injuries result in loss of function (sensory or motor or both) and disfigurement that must be considered serious even though the extent of the injuries may be small. These critical anatomic areas include the face, hands, feet, external genitalia, neck, and joint surfaces. Persons with preexisting renal, cardiovascular, or pulmonary disease cannot tolerate burn injuries as well as those without such disease. For persons with occlusive vascular disease, burn injuries to the lower extremities (especially the feet) are particularly serious. For adults with peripheral arteriosclerosis, gangrene requiring amputation is not uncommon after burn injuries to the feet or legs.

TABLE 3. Characteristics of selected epidemiologic studies of burn injuries

Year(s) of study	Number of cases	Subjects* I	Subjects* I+O	Data collection† RR	Data collection† FU	Source: (Reference #)
1970	100	X			X	41
1972-1973	155	X		X		42
1970-1975	411	X			X	15
1965-1974	386	X		X		43
1972-1975	1,049		X	X		44
1974	380		X	X		45
1974	2,862	X		X		6
1974-1975	1,165	X		X		8
1974-1975	2,927	X		X		46
1973-1976	2,729		X	X		47
1976	200	X		X		48
1974-1977	822	X		X		49

NOTE None of these studies distinguished between burn injuries resulting from fire disasters (fires that cause at least three deaths) and those resulting from fires not classified as disasters

*I = inpatients; I+O = inpatients and outpatients
†RR = record review, FU = follow up.

TABLE 4. Incidence of fire disasters and associated mortality, United States, 1980-1984

TOTAL Year	Number of fire disasters	Number of deaths	Average number of deaths/disaster
1980	326	1,356	4.2
1981	296	1,179	4.0
1982	266	1,111	4.2
1983	259	986	3.8
1984	244	1,007	4.1
TOTAL	**1,391**	**5,639**	**4.1**

Source: Reference *50*

Burn injuries may lead to new cardiovascular or pulmonary disease. The most common types of pulmonary disease include pneumonia and atelectasis. Ophthalmic (57), renal (58), and neurologic (59) disease may develop after some types of burn injuries.

Two major types of concomitant injuries may result from catastrophic events that cause burn injuries: inhalation injuries and fractures. An inhalation injury is caused by breathing in noxious gases and is the most serious concomitant injury (60). Smoke from some fires contains nitrogen dioxide and sulfur dioxide, which may cause bronchiolitis (61), alveolitis (62), and broncospasm (63). Clinical features of inhalation injury include nasal-membrane irritation, pharyngeal edema, hoarseness, and bronchorrhea. Fractures may also compound the burn injury in accordance with their severity The presence of fractures in association with burns complicates treatment and prognosis for both the burn injury and fracture (64,65).

Inhalation injury is even more important in the context of fire-disaster-related mortality. Most victims succumb to the asphyxiating effect of carbon monoxide long before the flames or heat affect them directly (66,67). Also, carbon dioxide poisoning or oxygen deficiency may play a role (68). During fire disasters within buildings, the confines of the structure assist in retaining and concentrating the toxic combustion products and smoke from the fire (69,70). A smoldering mattress or sofa in a standard-size room can produce lethal levels of carbon monoxide in as little as 30 seconds (71).

TABLE 5. Frequency and percentage distribution of fire disasters, by number of deaths/fire, United States, 1980-1984

Number of deaths/disaster	Number of fire disasters	Percentage of fire disasters
3	777	55.8
4	336	24.1
5	135	9.7
6	57	4.1
7	39	2.8
8	18	1.3
9	4	0.3
≥10	26	1.9
TOTAL	**1,391**	**100.0**

Source: Reference *50*.

It is also important to realize that fire-associated mortality may not result directly from the fire or its products. First, some natural deaths may cause a fire to start after the death (71)—e.g., a fatal cardiac collapse while smoking, while using matches or a lighter, or while being near an open flame (candle or stove). Although fire fighters are one of the occupational groups at greatest risk of dying on the job, the direct effects of fires are not the greatest killers (72). The most prevalent causes of death while responding to fires are heart attacks and vehicular accidents (72).

Contemporary Fire Disasters: Place of Occurrence

In the contemporary world, fire involving heat generation from burning fuel is converted into electrical/mechanical energy and does practically all the work of industrialized countries. Ironically, the current public health risks of fire disasters in the United States occur away from places in which fire does the work. Furthermore, the relative importance of many locations involved in historical fire disasters (Table 2) has decreased, and a different high-risk location for fire disasters has emerged that deserves the greatest public health concern and emphasis.

According to a Metropolitan Life Insurance Company study, fires accounted for 31.2% of all disasters in the United States in the period 1941-1975 (Table 6). Furthermore, fires accounted for 26.9% of all disaster-associated mortality In these fire disasters, 68.3% of the incidents and 47.1% of the associated deaths occurred in houses or apartments. Temporary public residences (hotels and boarding houses), treatment centers (nursing homes and hospitals), and public places accounted for only 7.4%, 4.3%, and 0.9%, respectively, of all fire disasters.

TABLE 6. Civilian disasters and associated deaths, by type of disaster, United States, 1941-1975

Type of disaster	Number of incidents	Number of deaths
Fire and explosion	1,369	12,128
Houses, apartments	935	5,716
Hotels, boarding houses	101	1,072
Hospitals, nursing homes	59	861
Public places	12	835
Other	262	3,644
Motor vehicle	1,659	10,516
Air transportation	471	7,756
Water transportation	225	2,226
Railroad	78	1,342
Weather phenomenon	335	8,279
Mines and quarries	94	1,612
All other	162	1,252
TOTAL	**4,393**	**45,117**

Source Reference 4.

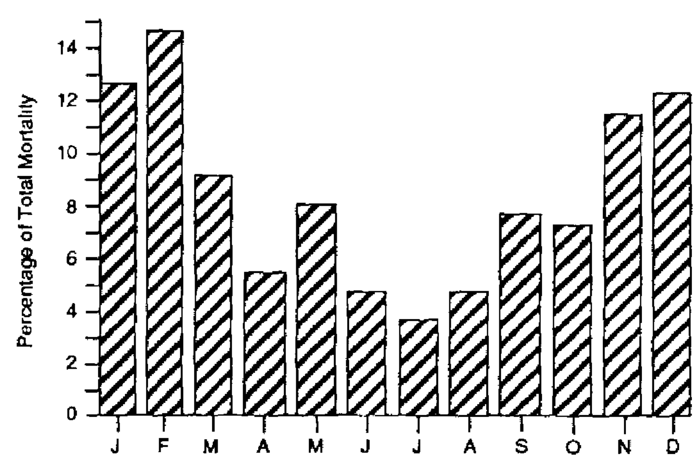
More recent data from the NFPA show that in the United States in 1980-1984, 87.5% of all fire disasters and 83.5% of all associated deaths occurred in residential properties (50). For 1984, 67.2% of all residential fire disasters occurred in one- or two-family dwellings (excluding mobile homes), 16.3% occurred in apartments, 10.9% occurred in mobile homes, and 6.6% occurred in rooming or lodging facilities. Therefore, from a public health perspective, any focus on fire disasters should emphasis occurrences involving single-family residences or duplexes.

Environmental and Human Descriptive Characteristics

NFPA data for the United States fire disaster experience in the period 1980-1984 have been reported according to four broad regions—Northeast, North Central, South, and West. For this reference period, fire disaster death rates (per 1 million persons) were 6.2, 5.3, 5.6, and 3.0, respectively, for these regions. Overall and for each year within this 5-year period, residents of the West had the lowest rate, while those of the Northeast had the highest rate. It is extremely difficult to draw any conclusions about these experiences because of unknown contributions made by many different factors—including climate, socioeconomic status, amount of urbanization, population density, and the age and construction of buildings.

Available information pertaining to the 1984 monthly distribution of fire disaster mortality is shown in Figure 2. Published statistics do not include information about the monthly distribution of incidents. Therefore, the observed differences among months may result from variation among the numbers of incidents and/or the average number of deaths per incident. Months associated with cold weather account for the largest percentages of deaths. December, January, and February accounted for 39.3% of all mortality. Further analysis by the NFPA showed that at least 25% of all deaths during these 3 months were associated with some type of heating equipment. However, these months still appear to have an excess mortality above that attributable to heating equipment.

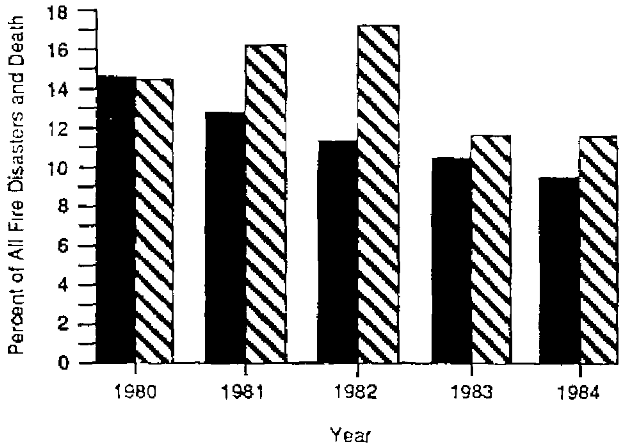
FIGURE 2. Percentage distribution of fire-disaster mortality, by month, United States, 1984



Source Reference 50

With reference to accidental versus nonaccidental causes, NFPA data shown in Figure 3 indicate that for 1980-1984, incendiary (deliberately set) fires accounted for 12% of all fire disasters, with an annual range of 9.4% (1984) to 14.7% (1980). This annual percentage distribution implies a decreasing importance of nonaccidental causes for fire disasters. The data on annual deaths associated with incendiary fire disasters show that for the same period, 14.3% of all fire

FIGURE 3. Percentage distribution of incendiary fire disasters and associated mortality, United States, 1980-1984



Source: Reference *50*

disaster deaths were associated with this cause, with a range of 11.5% (1983, 1984) to 17.1% (1982). These data indicate that incendiary fire disasters tend to result in larger numbers of fatalities. There appear to be two explanations for this trend. First, incendiary fires are more likely to take place in nonresidential locations containing more people. In 1980-1984, incendiary fires accounted for 32% of all nonresidential fire disasters and only 16.2% of all residential fire disasters. Second, other NFPA data show that 44.8% of all incendiary and 'suspicious" fire disasters originated in egress areas. Blocked exits apparently create a greater risk that persons inside will die.

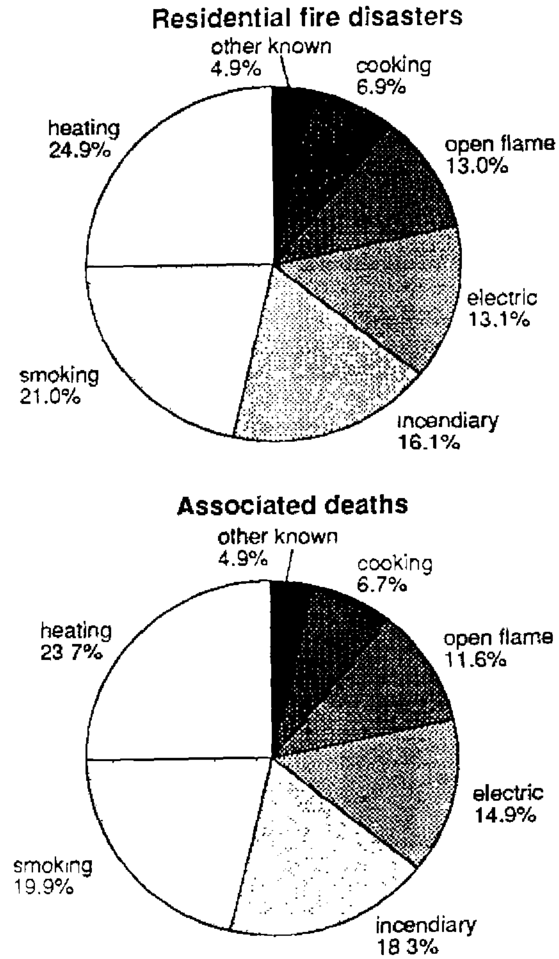
It has already been shown that in contemporary America the vast majority of all fire disasters and associated mortality have occurred in residential properties, mainly in single-family homes and duplexes. A recent control strategy designed to minimize the risks of being in such locations during fires is the installation of smoke detectors. In 1984, 74.1% of both residential fire disasters and associated mortality occurred in dwellings with no smoke detectors. These statistics do not account for instances in which detectors are present but improperly installed or maintained. Although apparently no comparable denominator data are available, these percentages appear spuriously large. The importance of this control strategy is perhaps best supported by statistics pertaining to the time of day at which these disasters occur. In 1984, 66.8% of all residential fire disasters occurred between 12:00 midnight and 8:00 a.m. In conclusion, given this trend in the time of occurrence and the greater influence of smoke and combustion products compared with the flames on the risk of mortality, proper utilization of smoke detectors seems to be an essential public health prevention strategy.

NFPA statistics pertaining to sources of ignition of residential fire disasters and mortality are shown in Figure 4. The largest source of ignition for both incidents and deaths has been heating equipment. For this category, > 90% involved auxiliary heating equipment rather than principal sources. In 1980-1984, of all residential fire disasters that involved auxiliary heaters, 41.1% involved fixed heaters (wall heaters, wood stoves, etc.; 38.9%, portable heaters; 8.2%, chimneys; 5.6%, fireplaces; and 6.3%, connections.

The second leading source of ignition for residential fire disasters is smoking. For this category, the incident distribution by specific location includes the living room (72.4% of the incidents and 73.4% of the deaths), bedroom (19.9% of the incidents and 19.2% of the deaths), and the kitchen (4.6% of the incidents and 4.7% of the deaths). Since most such incidents occur late at night or early in the morning, a likely scenario appears to be that persons fall asleep while smoking in the living room or bedroom.

The third and fourth leading categories of ignition in residential fires are arson and electricity, respectively. Both sources account for more deaths per incident than do the other sources of ignition. Many points addressed in the discussion of incendiary fires would be applicable here as well. Fire disasters due to arson and electricity in residential locations may more frequently involve a) elimination of the capability to exit or b) multiple sites of ignition. The greater contribution to mortality by electricity may involve fixed wiring located in concealed spaces. Consequently, when such fires start, they may go undetected longer and place residents at greater danger.

FIGURE 4. Residential fire disasters and mortality, by source of ignition, United States, 1980-1984



Source: Reference 50.

The fifth leading category of ignition is open flames. For this category, leading sources of open flames are matches (39.9%), lighters (25.7%), and candles (22.3%). Probably the most important statistic is the percentage of all residential fire disasters caused by children using (playing with) matches. Approximately 11% of all residential fire disasters begin this way, an important but much smaller contribution than has been traditionally perceived by the public and by many public health professionals.

Of the host characteristics that have been assessed, age appears to be an important risk factor. In 1984, 53% of all persons killed in residential fire disasters were < 15 years of age, compared with only 22.2% of the general population at risk (50). Persons in this age group may be either too young to react on their own or may react improperly because of insufficient knowledge of safe behavior. Interestingly, elderly persons (> 65 years of age) accounted for only 5.8% deaths in all residential fire disasters and did not represent a high-risk group. However, this may merely be a consequence of either living singly, in couples, or in nursing homes which, by definition, would not place them at risk from residential fire disasters.

Although not specific to catastrophic fires alone, an important host characteristic for sustaining burn injuries is any predisposing medical factor. In one study of 500 hospitalized adult burn patients, the vague term "poor judgment" was implicated in persons having sustained burn injuries (73). Elderly adults are more prone to severe burn injuries than are younger adults, possibly because of more limited defensive and reactive capabilities (74). Data from three studies of adult burn injuries that examined the contributory influence of predisposing medical factors are shown in Table 7 (74, 75). Approximately one-fourth of all adults who sustained burn injuries had some type of predisposing factor. These studies show that the two most important factors are alcoholism and epilepsy. Other studies have shown that 5%-10% of all adult burn injuries are sustained by individuals subject to epileptic seizures (77-82), and that alcoholism also plays a prominent role in the occurrence of adult burn injuries (83,84).

Prevention Strategies

Epidemiology: Surveillance and Research

Epidemiology can play an important role in preventing or mitigating the adverse public health impact of fire disasters. To date, this role has been extremely limited and used primarily to discern the differences in efficacy among various clinical strategies for treating persons with serious burn injuries. Although associated epidemiologic activities have focused largely on generic burn injuries or burn injuries associated with a specific type of location (workplace, home, recreation, etc.), the need for separating burn injuries by severity of incident (disaster versus nondisaster) has apparently not been totally recognized

As mentioned earlier, few descriptive or analytic data on the adverse public health impact of fire disasters are available. Data are basically limited to surveillance statistics maintained and published by a few agencies and gathered from case reports of fire disasters. Limitations in these data include the lack of denominator data needed to draw more valid conclusions about risk factors, insufficient description of associated morbidity, and failure to distinguish between characteristics and risk factors of fire disasters that are unique versus those that are similar for all types of fires.

A full spectrum of epidemiologic activities encompassing both surveillance and research would almost certainly assist in the further prevention or mitigation of fire-associated mortality and morbidity.

Engineering and Legal Controls

Many people may not be aware that the general acceptance of skyscrapers and high-rise buildings in the United States has resulted in part from the identification, establishment, and enforcement of building codes. The concept and adoption of building codes in this country can hardly be considered a new prevention strategy.

TABLE 7. Frequency and percentage distribution of predisposing medical factors causally associated with burn injuries sustained by adults, three studies

Predisposing medical factor	Pegg et al. (15) (n=411)		MacLeod (74) (n=723)		Pegg (75) (n=170)	
	Number	Percentage*	Number	Percentage*	Number	Percentage*
Alcoholism	26	6.3	65	9.0	12	7.1
Epilepsy	11	2.7	27	3.7	9	5.3
Psychosis, neurosis	8	1.9	19	2.6	8	4.7
Drugs	6	1.5	17	2.4	5	2.9
Suicide	11	2.7	4	0.6	4	2.4
Mental defect	9	2.2	4	0.6	3	1.8
Syncope	NR†	NR†	8	1.1	4	2.4
Diabetes	7	1.7	4	0.6	2	1.2
Other	20	4.9	18	2.5	1	0.6
TOTAL	**98**	**23.9**	**166**	**23.1**	**48**	**28.4**

*Expressed as percentage of total burn injuries in the study
†NR = Not reported

Source References 15, 75, 76

The first U.S. building codes were implemented by municipalities in the late 19th century. These early codes addressed the prevention of conflagration and were designed to minimize the risks that fires would spread to neighboring buildings. These codes provided specifications for roofing and exterior materials and characteristics (such as thickness and fire resistance) of common walls.

At the initiation of insurance companies, the National Fire Protection Agency (NFPA) was established in 1896. This organization has played a vital role in augmenting building codes and regulations. For example, codes have been developed for addressing such issues as fire-wall performance, separation between freestanding structures, and storage of combustible materials.

The evolution of codes is in some ways associated with the evolution of fire disasters in this country. The early threats of fire disaster focused around urban conflagration. Today, with peacetime conditions, this type of fire disaster represents little public health threat. The chief concerns today deal with fire inside—rather than among—buildings that are primarily residential. For the threat of fires within commercial buildings, codes provide for public safety by detailing stipulations for interior passages, stairwells, and doors. These codes provide for protective strategies involving containment of fire and/or evacuation of people.

Although the greatest contemporary risk of fire disaster involves single-family residences and duplexes, the thrust of building codes for these structures is different in several ways. First, these codes tend to involve less expensive strategies since individuals rather than businesses must bear the cost. Second, the containment of fire within certain areas of the structure is not a viable approach because of the size of residences. Third, because of the lack of access for inspection and the number of residential buildings, codes that require routine inspection of visible structures are not practical. Consequently, residential building codes have focused on structures not seen or difficult to correct—e.g., the design of chimneys and the placement of electrical circuits and wiring. These codes are enforced when the building is being constructed (or remodeled).

A recent engineering control that increases the length of warning time and represents a fairly inexpensive investment that can be made at any time is the smoke detector. The data presented, though limited, support the greater need for this control to be utilized within residential homes.

Mitigation Response and Suppression

In the United States, the training of fire fighters and the fighting of fires are old and established practices. The earliest response to fires consisted of ad hoc bucket brigades. The first fire-fighting company of trained individuals was founded in the 1730s by Benjamin Franklin (1).

The development of fire-fighting techniques for control and prevention of fires has augmented codes to minimize the risk of fire for whole sections of cities and communities. An important but often unrecognized function of fire departments is the inspection of buildings to enforce compliance with codes that govern construction, maintenance, and occupancy. However, the focus of most activity associated with this function is on nonresidential structures. Also, some of the fire-fighting strategies for large buildings are not suited for single-family dwellings and duplexes. For example, a house fire cannot purposely be allowed to burn beyond the room in which it started since there is no realistic way to contain it before it envelops the entire structure.

However, the ability of fire departments to reach any portion of their catchment area within minutes of receiving a fire alarm has minimized the risk of injury to persons and damage to property once residential fires have started and been discovered. Each year in the United States, fire departments respond to approximately 1 million residential fires (1). Given the amount of resources committed to and the realized accomplishments of this prevention strategy, additional substantial improvements in fire-fighting strategy that would further impact on the public health implications of fire disasters are not very likely.

Medical Treatment and Rehabilitation

Extensive clinical and epidemiologic work has focused on the triage, management, and rehabilitation of victims of fire disasters (85-89). Also, the emergency-medical-care components of disaster plans have been successfully implemented, as was the case when 1,700 fire victims from the MGM Grand Hotel fire were cared for (90). Prior discussions about the medical implications and severity of burn injuries are only slightly indicative of the tremendous amount of scientific knowledge currently available concerning the medical consequences of and treatment for burn injuries. Burn units in hospitals or entire hospitals devoted to burns operate throughout the United States. Surgical and medical treatment has not only maximized the likelihood of survival but also the aesthetic and functional potential for victims of serious burns.

As a means of tertiary prevention, medical treatment and rehabilitation have reached a plateau in ensuring survivorship and reducing morbidity associated with fire disasters. Further, significant reductions in fire disaster morbidity and mortality depend heavily on primary prevention approaches. These approaches entail activities directed during the pre-event phase of the disaster to prevent fires, reduce human exposure to the thermal energy of fire, or decrease the susceptibility of humans to injury. Primary prevention approaches should not only minimize public health impacts but may also improve adverse economic and social conditions associated with fire disasters. To realize future reductions in the public health impacts of fire disasters, it seems more efficacious to expend any additional resources on primary prevention strategies, such as public education and awareness.

Public Awareness and Education

As with any public health problem, once risk factors and prevention strategies have been identified and accepted by research and public health professionals, any reduction in the magnitude of the problem depends upon the awareness and education of the public at risk. Certainly, fire disasters are no exception. In fact, the need for public awareness and education may be more important for fire disasters than for other public health problems if one considers the size of the population at risk and the incidence of fires. Most of the U.S. population lives in single-family homes or duplexes, and 1 million fires occur in such residencies each year.

Persons need to understand the risk of fire disasters associated with their residences. Since 1980, major fires in hotels that received national attention have sensitized the portion of the public who regularly use hotels to the need to be knowledgeable about appropriate means of egress and reaction during fires. However, the entire adult public should be able to apply the same basic knowledge to fires in their homes Children who are old enough should be trained by their parents and teachers about what to do if there is a fire, and plans should be made to take care of young children. Families should hold rehearsals to help instill appropriate actions. Adults should recognize the risks that auxiliary heaters and cigarettes pose as sources of ignition for residential fires. Efforts should be made to install and maintain smoke detectors on each level of the home. These are just a few of many examples of the ways that the public needs to become aware of and educated about fire disasters.

Critical Gaps in Knowledge

Public health professionals may lack knowledge concerning the characteristics and public health impact of fire disasters in the United States. Their concept of a fire disaster should be adjusted to reflect a large frequency of incidents, each of which involves only a few deaths and usually occurs in the home. Although quite different from what is usually perceived to be a disaster, this kind of incident represents the contemporary fire disaster problem.

Current data for fires and fire disasters are inadequate—in terms of completeness, accuracy, and comparability (2). Sources of data include the National Center for Health Statistics, the National Fire Protection Agency, various members of the insurance industry, the National Fire Protection and Control Administration, the National Household Fire Survey, and reports from State Fire Marshals. Statistics published by various sources may differ because of different objectives, assumptions, and methods of collection and analysis. Much of the data in this chapter represents statistics published by the National Fire Protection Agency and appear to be the most comprehensive and detailed information available. However, it is uncertain how they vary from data collected by other sources.

Very little information is available on morbidity associated with fire disasters. Most available information does not cover nonfatal injuries. It is presumed that—as with other injury scenarios—numerous serious burn injuries and even more minor burn injuries occur for every fatality associated with a fire disaster. Given the potential for the tremendous burden of hospitalization for burn injuries on medical, economic, and social systems, sufficient public health knowledge about these injuries is essential.

Detailed information for risk assessment is lacking. Available data for fire disasters are mainly limited to surveillance data based on the aggregation of individual case reports. With the lack of denominator data and detailed characteristics, only crude conclusions about risk can be drawn. Furthermore, existing data make it extremely difficult to determine the efficacy of various types of prevention strategies.

Current literature does not directly address differences and similarities between fire disasters and all fire incidents. It is helpful to understand which characteristics of fire disasters are unique and which are similar for all types of fires. This understanding would assist in setting priorities for research needs and detailed preventive strategies.

Fire disasters may often be thought to result from a single causal factor. Some examples exist in which several factors are considered jointly to better understand the disaster scenario and the relative contributions of individual factors. Professionals have used stratified analyses, but have encountered problems because of the necessity of using small numbers. In some instances in the literature even the most frequent pattern of factors is relatively unimportant because it represents only a small percentage of fires. An increased knowledge of the comparability of databases is essential in order to facilitate aggregation so that larger numbers may be obtained for multivariate statistical analyses.

A review of the literature did not provide a complete appreciation for the operating assumptions adopted by groups addressing either the prevention or suppression of fires. With public health implications, there appear to be two different assumptions—the goal may be to prevent the initiation of the fire, or the goal may be to control the fire or evacuate the people. Such knowledge would be helpful in developing a thorough understanding of progress to date and in anticipating future needs and advances of these groups.

Most deaths from fire disasters result from the inhalation of combustion materials produced by the fire. Some of the related fundamental knowledge needed for prevention includes how gases are produced by and distributed during a fire disaster and how best to detect and warn potential victims about the presence of such gases. General gas processes in a fire disaster need to be better understood as they pertain to ignition, smoldering combustion, early stages and spread of flaming combustion, and distribution dynamics in rooms and corridors.

Most building codes in the United States focus on nonresidential buildings, although existing data show that the contemporary problem of fire disasters is with residential structures. More information is needed concerning the appropriateness and effectiveness of augmenting existing residential building codes.

It has already been mentioned that the threat of urban conflagration in peacetime is not a major public health problem. However, there is a critical knowledge gap concerning the potential new threat of suburban conflagration in some states. For example, to minimize the potential of erosion in some desert states, the chaparral has been allowed to remain close to walls or yards in hillside residential and commercial developments. This practice may increase the risk of conflagration from brush fires.

As with most public health problems in this country, state and federal efforts to prevent fire disasters augment those activities at the local level. Currently, there is a lack of detailed knowledge about strength, success, and needs of local efforts.

A key prevention strategy appears to be public awareness and education. Yet, the extent of the general public's basic understanding of fire disasters is unclear. More knowledge about baseline levels is needed, especially for high-risk parts of the country.

Public Health and Research Recommendations

The following activities are recommended in efforts to improve the identification and efficacy of prevention strategies designed to prevent or mitigate public health impacts of fire disasters:

1. The public and health professionals should become better educated about the true, insidious nature of contemporary fire disasters.

2. Appropriate agencies and public health professionals should develop greater concern for and focus more efforts on morbidity from fire disasters.

3. Efforts should be undertaken to maximize uniformity and comparability of data sources.

4. Existing data systems should be modified or new systems developed as appropriate to provide descriptive data with more detailed characteristics of human and environmental factors and applicable denominator data.

5. Since most information about characteristics and the public health impact of fire disasters derives from surveillance, efforts are needed to design and conduct epidemiologic studies that provide analytical data about risk factors.

6. Through consultation with appropriate fire prevention agencies, the need for specific epidemiologic studies should be determined and supported. For example, population surveys of level of education or safety practices are appropriate. Also, most available information focuses on the environmental characteristics of fire disasters. More emphasis on the epidemiologic characteristics of the host is needed so that the importance of such factors as behavior, knowledge, awareness, planning, perception, and predisposing medical factors can be determined more accurately. Arson specialists should be consulted to determine the need for epidemiologic assistance with the evaluation of incendiary fire disasters.

7. Prevention strategies need to encompass specific actions to address and minimize the risk of young children who are dependent on the knowledge and behavior of others.

8. More scientific information should be obtained that specifically addresses the adverse mental health impact on victims of and fire fighters involved with fire disasters.

9. More efforts should support the attempts by groups such as health departments, fire departments, and civic associations to determine the extent of and provision for smoke detectors in residential dwellings.

10. Fire-protection professionals should increase emphasis on public education and awareness of the proper selection, installation, usage, and maintenance of auxiliary heaters.

11. Public health and fire-protection professionals should stress that cigarette smoking is potentially dangerous—not only in terms of personal health—but also as a cause of fire disasters that destroy lives and property.

Summary

Contemporary fire disasters should be viewed as an unnecessary and preventable problem that deserves the attention and efforts of public health professionals—particularly in the United States, where the problems associated with fires are greater than in many other developed countries.

The literature contains limited statistics about the characteristics and adverse public health impact of fire disasters. However, these data still allow for identifying important contributions to fire disasters such as the role of residential fires, sources of ignition that include auxiliary heaters and cigarettes, and the need for widespread use of smoke detectors.

Appropriate public health prevention strategies appear to divide into five broad categories of activities: epidemiologic surveillance and research, engineering and legal controls, mitigation response and suppression, medical treatment and rehabilitation, and public awareness and education.

Additional efforts are needed in this field if the adverse public health impact of fire disasters is to be reduced further.

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