Chapter 2
Fire Fatalities and Fatal Fires – Risk Factors and Risk Groups

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Abstract Knowledge of the relevant risk factors is a prerequisite for effective strategies to prevent fatal residential fires. The aim of this chapter is to present the most important known risk factors for residential fire fatalities.

This review of the literature concentrates on various characteristics of the individuals and households experiencing fatal residential fires. We have chosen not to include various types of fire safety measures in this review, such as smoke alarms, fire extinguishers, or mobile sprinklers, as these are the subject of another chapter.

The literature studied provides a reasonably consistent picture of several basic risk factors for death in a residential fire. With respect to age, the oldest have the highest risk. Among children, it is the youngest who have the highest risk. In all age groups, men are at greater risk than women. Smoking and alcohol have a large effect on risk. Certain socio-demographic factors are clearly associated with higher risk, such as living alone, having a low income, or being unemployed. In addition, individuals with functional limitations are at greater risk than others. These risk factors have been observed to hold true over an extended period of time in several countries, despite a gradual decrease in the mortality rate from residential fires in the last decades.

We note that much of the research on risk factors is relatively old, and many studies are of a descriptive nature. It is clear that many of the risk factors identified in the research are correlated. It is desirable that future studies take more account of covariation between the various risk factors and control for confounding factors. In addition, large-scale population-based case-control or cohort studies have the potential to provide a deeper understanding of risk factors for residential fire fatalities.

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1 Introduction

Knowledge about risk factors plays a central role when formulating a fire safety strategy or designing a specific intervention to improve fire safety. The objective of such interventions may be to avoid fires by reducing the likelihood of a fire occurring in the first place, or to reduce the likelihood of an initial fire leading to serious outcomes such as a fatality. An understanding of risk factors will make it more likely that an intervention will be effective in fulfilling either of these objectives.

The aim of this chapter is to present current knowledge on risk factors for dying in a residential fire. Results from various research studies are presented, together with analysis in the form of reports from the fire authorities.

It would have been desirable to conduct a systematic review of all available literature, but there are some drawbacks to such an approach. Systematic reviews often have a high bar for academic rigour, with only a small selection of work being included. Important factors can be missed by this approach. However, research into risk factors has been ongoing for fifty years, so if the selection criteria are relaxed, then it is easy to end up with too much material to analyse.

This chapter is based on a more pragmatic approach. We make no claim to provide a comprehensive list of all the risk factors for death in a residential fire, but our intention is to include the most important factors identified over the last fifty years. We focus on the United States, Canada, Australia, New Zealand, the United Kingdom, and Scandinavia, as most of the published research comes from these countries.

A majority of research on risk factors with regard to residential fires has focused on fire death, in part perhaps because this is a well-defined fire outcome with a manageable number of cases to study. In addition, data are more readily available, since the police and medical authorities pay particular attention to these events, ascertaining the circumstances that lead to the fire and the cause of death.

Both early research [1] and research in recent years [2] have shown that there are significant differences between characteristics of the fires and the victims when different levels of residential fire outcomes are studied: death, non-fatal injury, and property damage. This would seem to indicate that there are different risk factors at play for the different fire outcomes. There are sufficient differences to warrant caution in assuming that fatal fires form part of the same spectrum as other fire outcomes.

This chapter focuses on risk factors for fatal residential fires, and it is important for the reader to note that a risk factor for one particular fire outcome will not necessarily hold true for other outcomes. There is more to read about these differences in

Chap. 3. Non-fatal Fires – The Injury pyramid, Socio-demographic Gradients and Protective factors.

2 Terminology

Most people have an intuitive understanding of what is meant by "risk factor". However, before proceeding with the main content of the chapter, it is worth defining some of the most important terms used in relation to risk factors.

A risk factor is any factor that precedes and is associated with a higher likelihood of a negative outcome (in our case, death due to a residential fire). Conversely, a protective factor is a characteristic associated with a lower likelihood of a negative outcome or an impact reduction of a risk factor. In many cases, a risk factor is the opposite of the protective factor. For example, while having a functional smoke alarm can be a protective factor, not having one can be a risk factor.

Some risk factors are fixed, which means that they cannot be manipulated and will not change over time. This type of risk factor is termed a *fixed marker* or *risk indicator*. Sex and race are examples of fixed markers.

Other risk factors are considered variable and can change over time. There are two types of variable risk factors. Those that when manipulated, change the probability of the outcome (*causal risk factor*) and those that do not change the probability of the outcome (*variable marker*). To reduce the incidence of the outcome of interest, interventions must focus on causal risk factors. Further, the focus should generally be on the causal risk factors having the greatest impact on their target population. The correlation between a causal risk factor and an outcome must not only be statistically significant but also be expected to produce a meaningful reduction in the outcome of interest. This does not mean that risk factors other than causal risk factors are of no interest. On the contrary, they are very useful, for example when identifying high-risk populations for prevention. However, changing them will not reduce the incidence of the negative outcome.

In order to ascertain whether a certain variable is a risk factor or not, the outcome must be related to something. If we, for example, want to study the factor sex, fatalities among men must be related to the number of men in the population under study, and this rate must be compared to fatalities among women in relation to the number of women in the population. These rates are compared for men and women to see if sex would appear to affect an individual's risk.

It is most common to search for risk factors related to individuals, but risk factors can also concern other subjects such as households, fires, or geographical areas. It is important to point out that risk factors are specific to their subject. For example, a relationship observed for a geographical area does not necessarily hold true for a particular individual living in that area. This common pitfall is called *the ecological fallacy*: an incorrect assumption about an individual based on aggregate data for a group.

Studies on risk factors often use the term *risk group*. Risk groups are used to describe individuals sharing traits that increase their probability of dying in a residential fire (or households with traits that increase their probability of being the scene of a fatal fire). One or more risk factors are used to divide the subjects into high-risk and low-risk groups.

Many studies of fire outcomes consider various circumstances without analysing them in relation to a relevant comparator. For example, there are many studies where it is observed that a large proportion of fatalities have a high level of alcohol in the blood. It is difficult to translate these observations into risk factors since we often lack a control group in the form of similar data for individuals not dying in fires. Circumstances which are observed often hold true but, without a clear indication of overrepresentation, are sometimes called *main characteristics*.

3 Delimitation

Many studies have shown that having a working smoke alarm in the home is associated with a lower fatality rate [3]. It has also been shown that smoke alarms are not evenly distributed across all households, and that households where fatal fires take place are less likely to have functional smoke alarms than households with reported fires or average households [4–6]. These observations indicate how important it is to continue the work of ensuring that more homes are protected by smoke alarms and also to understand in which situations a functional smoke alarm will not in itself be enough to avoid serious injury or death. However, we have chosen not to include various types of fire safety measures in this review (such as functional smoke alarm, fire extinguisher, or mobile sprinkler), even though not having them can be regarded as a risk factor. We refer the reader to the second part of this anthology, which goes into some detail about protective measures in the home.

4 Early Research

Residential fire research gained momentum in the 1970s in the wake of the report "America burning" from 1973 [7]. The report called for more emphasis on fire prevention and research to inform fire safety strategies. The background to the report was the Fire Research and Safety Act of 1968, which came in response to the marked increase in fire losses observed in the United States at the time.

Regarding fire deaths, early studies in the United States [8, 9] showed that the majority of fatalities occurred in residential fires. Toxic gases were identified as the primary cause of death, with carbon monoxide as an asphyxiant. Cigarettes were identified as a principal ignition source and alcohol was a significant contributory factor (particularly among men from 40 to 60 years of age). When comparing fatal fires with fires causing non-fatal injuries, it was noted that smoking was more

prevalent as the cause for fatal fires, and that the highest proportion of deaths to total fire victims occurred in the younger and older age groups [1].

At about the same time, fire deaths were studied in Glasgow, Scotland [10–12] and the study was subsequently extended to cover the whole of the United Kingdom [13]. Most of the deaths occurred in residential fires in which the fires were restricted to the room or area of origin. The fatal fires occurred more often during the winter and at weekends. Old people were particularly vulnerable in these fires. Alcohol was identified as a factor across the United Kingdom in general, and this was particularly apparent in Glasgow.

At around this time, there was also an increased interest in the fire problem across the Nordic countries. In Sweden, a governmental investigation and a research paper [14, 15] called for improved statistical data and more research. Two studies in Denmark [16, 17] showed that fire deaths caused by smoking were a serious problem, particularly in nursing homes or settings where social problems, psychiatric disorders, or alcohol abuse were present.

These early studies were mostly exploratory and descriptive in nature. They were most often carried out by medical doctors and few went beyond the collection of vital statistics. However, one important observation from this early research was that fire deaths were clearly not randomly distributed in the population.

5 Age and Sex

Age and sex are the most commonly investigated risk factors for death in residential fires [18, 19]. Datasets for fire fatalities almost always include age and sex. Most countries produce high quality vital statistics for comparison, making, for example, cross-sectional studies easy to perform. Early research identified young children and elderly people as those most at risk, and also noted the over-representation of males in all age groups [8]. The disproportionate percentage of fire victims in the youngest and oldest age groups has been shown repeatedly over the years and in many different countries [20–23].

The long-term trend in fire fatality rates (deaths per million people) and in absolute numbers has been declining in most countries for many decades [24, 25] with the greatest reduction being observed among children [26]. In the United States, the youngest group (0–4 years) has gone from having a higher frequency of fire deaths than expected to now lying below the average for the general population [20].

It is clear that few small children die in residential fires in the countries studied. However, children up to four years of age have an elevated risk of fire death when compared to older children (aged 5–14). Several factors make small children more exposed to fatal fires. Playing with fire is a common cause for fires involving children [27–29]. They also lack an understanding of the dangers associated with fire and often lack the capability to escape from a fire. Small children are often reliant on parents or other older individuals for their safety if a fire starts in a home.

Several socio-demographic factors have been shown to be related to child mortality in residential fires. One study showed that substandard housing and overcrowding are associated with an increased fire mortality rate among children [30]. Another study showed that lower educational attainment of the mother, younger age of the child, and more children in the household all increased the risk of fire death for children [31]. In Philadelphia, USA, census tracts with low income levels, high proportions of households with single parents, and a higher proportion of housing built before 1939 were linked to higher levels of child mortality in fires [32]. In Ontario, Canada, children from families receiving help from the Children's Aid Society had a substantially higher risk of dying in a fire [28].

One study showed that smoke alarm functionality in fires involving child fatalities was low [28]. It has also been shown that smoke alarms do not seem to provide effectively protection against death or injury in fires caused by children playing with fire [27].

It is probable that the relationship between socio-demographic factors and child fire mortality is largely due to environmental factors and the behaviour of adults. A Scottish study showed that deaths among children were largely the direct result of the actions of an adult, with smoking and alcohol playing an important role [33].

The risk of death is highest among the oldest individuals (85 and older). However, excess risk in relation to the general population occurs already at fifty (relative risk >1). Impaired movement, hearing, and smell together with slower reactions and memory problems are all presumed to increase the risk of the elderly. It has also been observed that they have a lower prevalence of smoke alarms. One review study [34] points out that there are both medical and biological factors which can influence their risk. Existing illness associated with old age can increase the risk of death among the elderly, for example heart disease dramatically increases vulnerability to carbon monoxide, and presumably also other suffocating gases.

One risk factor which is less pronounced among the elderly is the consumption of alcohol. When compared with younger fatalities, the elderly were significant less likely to have alcohol detected in their blood [35, 36].

Many studies have shown that males are at higher risk of death from residential fires than females. This is true for all age groups, but is particularly pronounced in the middle-age population. It is unclear exactly what lies behind this observation. However, some explanations seem more likely than others. High consumption of alcohol is probably one. This dominance of male fatalities also applies when looking at the absolute numbers, except for the oldest population due to there being so many more females than males in that age group.

Age and sex are risk markers rather than causal risk factors. However, an understanding of how, for example, fire causes and injury mechanisms differ by age and sex is important for identifying specific risk groups and the prevention strategies that are most appropriate for them [37].

6 Smoking and Alcohol

Smoking and alcohol consumption are two lifestyle behaviours often observed to be associated with fire deaths [18, 19]. In several studies "smoking materials" is the leading known source of ignition in fatal residential fires [38]. Fires ignited by smoking more often result in a fatality than fires ignited by other means [39]. One study has shown that when comparing fires caused by smoking with fires ignited by other means, the victim was more often asleep, in the room of fire origin, intoxicated by alcohol or psychotropic drugs or sedated, suffering from mental illness and was aged between 18 and 65. Considering the room of origin, smoking-related fatal fires more often started in a bedroom or living room [40]. Another study showed that smoking-related fatalities can be grouped into two very different types of fire scenario. The first mainly involves older women where the clothing is ignited (these often start in the kitchen), while the second involves mainly middle-aged men, often intoxicated, where the bed or couch is most likely ignited by the cigarette (these often occur in a bedroom or living room) [21].

As mentioned above, child's play is a common cause in fires where young children die. The heat source is often a cigarette lighter or matches and, since the availability of those can be expected to be higher in homes with smoking, smoking could be considered an indirect cause of many of those fire deaths [27].

Non-smokers may be at increased risk due to fire from the presence of smokers in their environment [41]. An American study observed that one out of four fatalities in smoking-material fires was not the smoker who started the fire [42]. This is in contrast to a recent Swedish study [43] which did not observe a similar phenomenon among fire victims, indicating that the threat posed by smokers to non-smokers in their surroundings is unclear at present, due to the limited number of studies.

At the ecological level, an American study has shown that death rates in residential fires are high in states with a high proportion of smokers, and this relationship holds true even when taking account of socio-economic factors such as education and median household income [44].

The association between alcohol intoxication and death in residential fire is also well-documented [45, 46]. Understanding the role played by alcohol seems essential when trying to determine why fire deaths occur. The consumption of alcohol is an obvious contributory factor that can influence the risk of death in many ways. Alcohol can play a direct role, for example if it causes someone to become unconscious while smoking or fall asleep while cooking. Intoxication can also affect responsiveness to fire cues, preventing a victim from hearing or correctly interpreting a fire alarm. The consumption of alcohol can also affect the effectiveness of escape measures. Being under the influence of alcohol might affect judgement, making a person less likely to avoid inherently dangerous situations that could give rise to burns. Alcohol can further affect a person's balance, causing them to fall. There is some evidence that alcohol in the blood accelerates behavioural incapacitation from toxic gases, such as carbon monoxide [45]. In addition, several studies

suggest that the probability of surviving serious burns is reduced for people with a history of alcohol abuse [45].

After a fire death, it is common for the blood alcohol content to be analysed in an autopsy. Several studies have observed a high proportion of adult victims testing positive for alcohol at the time of death. It is important to note the high level of intoxication in many of those testing positive for alcohol, one study estimating a mean value of 193.9 mg/dl [47].

It should be acknowledged that alcohol plays a role in more fires than those in which a victim tests positive for alcohol in the blood. It has been found that children and the very old account for 15% of the fatalities in alcohol-related fatal fires, without themselves drinking alcohol [48].

It is also interesting to note the differences between various age groups in the proportion of fatal fire victims testing positive for alcohol. The elderly are significantly less likely to have alcohol detected in their blood [46, 47, 49, 50]. The proportion of males testing positive for alcohol is higher than that for females [46, 49].

The consumption of alcohol has been shown to be more common in fatal fires caused by smoking or cooking than in fatal fires with other causes. The association between smoking and alcohol consumption in fatal fires has been pointed out in several studies [46, 51–53].

7 Living Alone or Being Home Alone at the Time of the Fire

When comparing fatal fires with non-fatal fires, early studies showed that being home alone at the time of the fire increases the risk of death [52, 54]. A similar association was later found at the individual level for the circumstance of living alone, by comparing individuals dying in residential fires with randomly selected individuals matched on sex and age [55] or with survivors in residential fires [56]. There are also many descriptive studies that have observed high percentages of victims in fatal fires with the characteristic of living alone or being home alone at the time of the fire, for example in London [57].

It is logical that being alone at home increases the risk of dying in a fire. If more than one person is present then it will be more likely that the fire is discovered and put out, or that a successful evacuation can take place. This is even more important if the person is especially vulnerable in a residential fire, for example due to old age in combination with impaired vision, hearing, or mobility. A recent ecological country-level study on older people (75 years and above) in Europe showed that when the share of older people living alone increased by one percentage point, the fire-related mortality increased by 4% [58]. It should, however, be noted that a part of the correlation between living alone and the risk of fatal fires is likely to be due to correlations with other important risk factors such as age and high alcohol consumption.

8 Socio-economic Factors

Low socio-economic status has been shown to be associated with an elevated risk of dying in a residential fire. Having low income [51, 55, 56], low educational attainment [51, 55], and being unemployed [55, 56] would all appear to be associated with greater risk of death. In addition, residents of rented housing [54–56, 59] may be at increased risk.

Consistent results have been observed, regardless of whether it is fires, individuals, or households that are being studied, and what they are being compared to. For example, low socio-economic status is associated with increased risk when:

- Comparing fatal with non-fatal fires [54]
- Comparing individuals dying in residential fires with survivors [56]
- Randomly selected individuals are matched on sex and age [55]
- Comparing households [51, 59]

Similar relationships have been observed at the ecological level. Studies from the United States have shown that the fire fatality rates were highest in areas where property rental values were low [60] and that housing age, the prevalence of mobile homes, and the proportion of the population in rented accommodation all have significant independent effects on fire death rates [61]. In New Zealand, the highest risk of death is observed in the most socio-economically deprived areas [62]. In England, fatal fire injury rates have been shown to increase with increasing levels of deprivation [63].

9 Race and Ethnicity

Studies in the United States report non-white populations to be at higher risk of both fatal and non-fatal injury, for both sexes and across all age groups [14]. In North Carolina, death rates for whites were one third of those for other races [64] and other US studies have shown that black individuals have a risk of fire death almost twice that of an individual of another race [39, 65].

However, the picture is far less clear when going beyond an analysis of crude death rates. For example, no association between race/ethnicity and fire fatalities was found when comparing victims with survivors from the same fire [47]. When comparing residential fire fatalities in Sweden with randomly selected controls matched on age and sex and taking socio-demographic factors into account, individuals born outside of Europe were found to have a lower risk [55].

Race and ethnicity are clearly associated with other factors that may have a greater impact on risk, for example socio-economic factors [66]. When large metropolitan counties in United States were studied at the ecological level, a significant interaction between the proportion of the population that was African American and median family income was observed. Counties with a high proportion of African

Americans in combination with low median family income showed extremely high fire death rates, suggesting the relationship to be multiplicative rather than additive [61].

10 Urban Versus Rural Residence

Studies have shown that living in rural areas is associated with a higher risk of residential fire death [55, 67]. A relationship that persists despite taking account of age, sex, and various socio-demographic factors [55]. When looking for plausible explanations, the longer response times of the emergency services in rural areas [68] and the lower presence of smoke detectors in fatal fires in rural locations [69] should be considered.

11 Functional Limitations

Physical and mental disabilities increase the risk of dying in a residential fire, making these groups particularly vulnerable. In the United States, it has been estimated that physical disability was a factor in 15% of home fire deaths [70]. Other international studies have also found that disability is a significant risk factor in unintentional residential fires. At least 21% of the victims in London suffered some form of disability [57]. In Denmark, one-fifth of the victims received disablement pension and two thirds of those over 67 years of age were disabled [71]. A recent Norwegian study observed that those over 67 years of age had reduced mobility, impaired cognition, and mental disorders as risk factors [23]. Fires where people with physical or mental disabilities were present were more likely to end up as a fatal fire [54]. At the individual level, when comparing people who died with survivors of the same residential fire, people with physical or cognitive disability have been shown to be at greater risk [48]. Another study compared survivors from residential fires where no one died with people who died in residential fires. This study showed that individuals who suffered some physical or mental illness or had some other pre-existing disability had a greater risk of dying in unintentional residential fires than those who did not [56]. Comparing residential fire fatalities with the general population matched on age and sex, no association could be observed between disability allowance and the risk of dying, once socio-demographic factors were taken into account [55].

In a study from Victoria, Australia, the mentally ill were overrepresented among fire fatalities. The association with known risk factors was assessed and it was highlighted that the mentally ill were much more likely to have combined alcohol and drugs prior to their death and to have a history of careless smoking [72]. See Chap. 5. The evacuation of people with functional limitations in residential fires for an

overview on the role of functional limitations on self-evacuation possibilities in the event of fire in a residential building.

12 Discussion

The aim of this chapter is to give an overview of risk factors for death in a residential fire. An understanding of risk factors is essential for effective measures to reduce fire deaths. In this review, we have focussed on factors concerning various characteristics of the individuals and households experiencing fatal residential fires, in relation to relevant comparators, for example, those of the general population, households in general, or survivors of residential fires.

Many characteristics found to be associated with increased risk, such as age, sex, or ethnicity, are fixed and are not in themselves causal risk factors. However, knowledge about these fixed markers is still very important, as it will assist fire prevention program developers in targeting interventions for those with the highest risk.

Being old, male, or living with some kind of physical or cognitive functional limitations are all factors that increase the risk of dying in a residential fire. Sociodemographic factors such as having a low income, low educational attainment, being unemployed, or living alone are also associated with a greater risk of death. Smoking and the consumption of alcohol are clearly two very important behavioural risk factors. The earliest research into risk factors showed that a large proportion of fatal fires were smoking-related and that many of those who died were under the influence of alcohol at the time of their death.

Several risk factors appear to be resistant to change, having been observed in early research and confirmed in more recent work. However, it should be remembered that technological and social advances can mean that early research no longer holds true. Over the years, considerable improvements have been made in fire safety due to improved regulation and an increase in smoke alarm ownership. In several countries, there has also been a reduction in smoking among the general population.

It must also be remembered that a risk factor in one place and time cannot be automatically assumed to hold true in other settings. Most of the studies in this review have come from the United States, Canada, Australia, New Zealand, the United Kingdom, and Scandinavia. There are many differences between these countries, and it is not clear whether risk factors observed here will hold true in other countries.

Many of the risk factors identified in this review are correlated. For example, low socio-economic status has been shown to be associated with other risk factors, such as smoking and the consumption of alcohol. The correlations among risk factors make it difficult to isolate the effect that every individual factor has on the risk of death in a residential fire. Ideally, those responsible for risk-based targeting of fire safety interventions would have an understanding of individual factors and how they interact. However, at present the complexities are far from completely understood.

13 Conclusions

The literature studied in the course of this review provides a reasonably consistent picture of several basic risk factors for death in a residential fire. For many fire safety practitioners, knowledge of these risk factors will be of help in designing effective fire safety interventions. However, at present the evidence is somewhat limited and a deeper understanding of risk factors would be beneficial. As pointed out in the introduction, many of the studies only go so far as to point out main characteristics, where a more rigourous analysis of overrepresentation is needed to identify risk factors. It is also desirable that future studies take more account of covariation between the various risk factors and control for confounding factors. In addition, large-scale population-based case-control or cohort studies have the potential to provide a deeper understanding of risk factors for residential fire fatalities.

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