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The state of the residential fire fatality problem in Sweden: Epidemiology, risk factors, and event typologies

Anders Jonsson, [a,b,*] Carl Bonander, [a,b] Finn Nilson, [a,b] Fredrik Huss [c,d]

[a] Division of Risk Management, Department of Environmental and Life Sciences, Karlstad University, Karlstad, Sweden
[b] Centre for Public Safety, Karlstad University, Sweden
[c] Burn Center, Department of Plastic and Maxillofacial Surgery, Uppsala University Hospital, Uppsala, Sweden
[d] Department of Surgical Sciences, Plastic Surgery, Uppsala University, Sweden

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ABSTRACT

Introduction: Residential fires represent the largest category of fatal fires in Sweden. The purpose of this study was to describe the epidemiology of fatal residential fires in Sweden and to identify clusters of events. *Method:* Data was collected from a database that combines information on fatal fires with data from forensic examinations and the Swedish Cause of Death-register. Mortality rates were calculated for different strata using population statistics and rescue service turnout reports. Cluster analysis was performed using multiple correspondence analysis with agglomerative hierarchical clustering. *Results:* Male sex, old age, smoking, and alcohol were identified as risk factors, and the most common primary injury diagnosis was exposure to toxic gases. Compared to non-fatal fires, fatal residential fires more often originated in the bedroom, were more often caused by smoking, and were more likely to occur at night. Six clusters were identified. The first two clusters were both smoking-related, but were separated into (1) fatalities that often involved elderly people, usually female, whose clothes were ignited (17% of the sample), (2) middle-aged (45–64 years old), (often) intoxicated men, where the fire usually originated in furniture (30%). Other clusters that were identified in the analysis were related to (3) fires caused by technical fault, started in electrical installations in single houses (13%), (4) cooking appliances left on (8%), (5) events with unknown cause, room and object of origin (25%), and (6) deliberately set fires (7%). *Conclusions:* Fatal residential fires were unevenly distributed in the Swedish population. To further reduce the incidence of fire mortality, specialized prevention efforts that focus on the different needs of each cluster are required. *Practical applications:* Cooperation between various societal functions, e.g. rescue services, elderly care, psychiatric clinics and other social services, with an application of both human and technological interventions, should reduce residential fire mortality in Sweden.

1. Introduction

Injuries and deaths caused by fire is a major public health problem, with more than 300,000 people being killed by fires around the world, annually (World Health Organization, WHO et al., 2004). Most deaths occur in low-income countries where the availability of preventive interventions, rescue services, and advanced trauma and burn care is limited. However, despite a steady decrease in many countries during the last decades, fatal fires are still a problem even in high-income countries (U.S. Fire Administration, 2011). Residential fires are by far the largest category of fatal fires in Sweden, accounting for about three-quarters of all fire-related fatalities (Jonsson, Bergqvist, & Andersson, 2015).

Fire-related mortality has been studied in depth in developed countries with risk factors and fatality characteristics regarding residential fires extensively described in the existing literature (e.g. Runyan, Bangdiwala, Linzer, Sacks, and Butts (1992); Barillo and Goode (1996); Leth, Gregersen, and Sabroe (1998), Marshall et al. (1998); Brennan (1999); Warda, Tenenbein, and Moffatt (1999); McGwin, Chapman, Rousculp, Robison, and Fine (2000); Istre, McCoy, Osborn, Barnard, and Bolton (2001); Duncanson, Woodward, and Reid (2002); Istre, McCoy, Carlin, and McClain (2002); Holborn, Nolan, and Golt (2003); Mulvaney et al. (2009); Turner et al. (2017)). Frequent results from such studies are that the very young, elderly, males, physically disabled as well as those impaired by alcohol or other substances are more likely to die in fires. Fatal fires are often associated with smoking materials and cooking, with victims often dying as a result of smoke inhalation. In terms of geographical aspects, rural communities have been shown to have the highest fire mortality rates. The poor, as well as those with low educational attainment, are more likely to die in residential fires

* Corresponding author at: Division of Risk Management, Department of Environmental and Life Sciences, Karlstad University, SE-651 88 Karlstad, Sweden.
E-mail address: anders.jonsson@kau.se (A. Jonsson).

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than others and the absence of a smoke alarm also appears to increase the risk of death in the event of a fire.

Recent studies add to and deepen the knowledge regarding specific risk groups using sub-group analyses to study heterogeneity in risk factors between groups. For example, Harpur, Boyce, and McConnell (2013), Harpur, Boyce, and McConnell (2014) investigated the circumstances surrounding fatal residential fires amongst the very young children and the elderly population, using coronial reports. Similarly, Graesser, Ball, and Bruck (2009) investigated risk factors for residential fire fatality across the lifespan, exploring differences in risk characteristics between age groups. Bruck, Ball, and Thomas (2011) compared the role of alcohol in residential fire deaths for different risk factors. The results from these studies, which make use of detailed data on both the fire event and the characteristics of the individuals involved, show promise in guiding fire mortality prevention strategies.

In this paper, we use a database on fatal fires compiled by Jonsson et al. (2015) that derives and links data from multiple sources to describe the epidemiology of residential fire deaths in Sweden in terms of detailed event and fatality characteristics. By doing this, previous research is improved in terms of details as the database uses several sources of information to gain more elaborate knowledge of the etiology of residential fire mortality in Sweden. The richness of the dataset also allows us to explore and classify events that share common features in terms of both the characteristics of the individuals involved, as well as the characteristics of the event itself. Thus, the purpose of this study is two-fold; (i) to describe the epidemiology of fatal residential fires in Sweden, and (ii) describe common typologies of these events by means of cluster analysis.

2. Materials and methods

2.1. Materials

The dataset used for this study is a subset of an already compiled database using linked individual- and event-level data from three different data sources covering all fatal fires in Sweden between January 1st, 1999 and December 31st, 2007. Included in the database are; the database on fatal fires, held by the Swedish Civil Contingencies Agency (MSB); the database on forensic examinations, held by the National Board of Forensic Medicine; and the Cause of Death Register, held by the National Board of Health and Welfare. For the purpose of this study, we extracted all recorded fatal residential fires from the compiled database. Due to the definitions used in the database on fatal fires, only victims who died as a direct effect of a fire or explosive combustion process are included. Thus, indirect fatalities, such as those caused by falling from heights after jumping from a burning building are not included. For the same reason, a second restriction is that the deaths had to occur within 30 days of the fire event. For further details regarding the data, matching methods, and compilation of the linked database, see Jonsson et al. (2015).

In addition to this, data on all residential fires attended by rescue services, for the same time period, were obtained from MSB in order to calculate fatality rates per rescue service-attended fire, and linked to the fatal fire events to gain supplementary information. MSB serves as the national focal point for fire prevention and keeps records of all emergency turnouts reported by local fire departments all over Sweden. The national register contains information on for example incident location including coordinates, type of building/object, cause of fire, object of origin, room of origin, fire size on arrival and fire spread.

Population statistics were obtained from Statistics Sweden in order to calculate exposure-time in terms of person-years, which were estimated by aggregating the end-year population of each year during the study period (1999–2007) for each age- and sex-specific group.

The final dataset contains data on two levels. At the event-level, the following variables were included: date, time of day, municipality, residential category, cause of fire, object of origin and room of origin. Further, by linking rescue service reports, we also could add the variables fire size on rescue service arrival and fire spread to supplement the event-level data. On the individual-level, the following variables were included: gender, age at death, primary injury diagnosis, blood alcohol concentration (BAC‰) and carboxyhemoglobin (COHb%). All variables and categories used for this study, including coding rules for the variables modified compared to the original data, are found in Tables A1 and A2 in Appendix 1.

Most of the modified variables, such as season and age group, are self-explanatory. Others require some further explanation. For instance, two different pre-defined municipality cluster classifications, based on different socio-demographic variables, were used in order to study aggregated socio-demographic aspects of fire mortality. The first classification, based on the municipality groups defined by the Swedish Association of Local Authorities and Regions (SKL, 2011), divides the municipalities into ten groups based on structural parameters such as population, commuting patterns, tourism and travel industry, and economic structure. The second classification, which is based on a more recent cluster analysis by Statisticon AB (Anders Sundström, Statisticon AB, Stockholm, Sweden, personal communication, December 9, 2015), creates five clusters of municipalities with common socioeconomic characteristics in terms of population structure, income, education, unemployment and sick leave. The classifications are detailed further in Appendix 2.

Based on the analyses performed by the forensic toxicology laboratory (that belongs to the National Board of Forensic Medicine), dichotomous variables were derived from the levels of alcohol and carboxyhemoglobin (COHb) in the blood of victims. Because of postmortem alcohol production, we used a threshold of 0.2‰ (20 mg/ml) (personal communication Anita Holmgren, June 23, 2015) when classifying a crude indicator variable for positive blood alcohol levels. Also, 0.2‰ is the current drink driving limit in Sweden, which serves as a further justification for the use of this value as a cutoff. Concentrations of COHb $\geq$50% are severely toxic and indicates carbon monoxide poisoning as the primary cause of death (Widdop, 2002) and was therefore used as a threshold in the COHb dummy variable.

2.2. Data analysis

First, mortality rates for different age- and sex-specific groups were calculated. The number of deaths within each group was divided by the number of person-years in that group and presented as the number per million population (pmp). To study between-group differences in intentionality, blood alcohol levels $\geq$0.2‰, COHb $\geq$50% and primary injury diagnosis, stratum-specific shares were calculated and presented with 95% confidence intervals assuming a Poisson distribution.

Next, incidence rates of fatal fires were calculated by dividing the number of fires for the different risk factors by the number of rescue service-attended fires, converted to the rate of fatal fires per 1000 fires. Similarly, fire rates were also calculated by dividing by days when comparing different seasons, by hours when comparing different time intervals and by population when comparing different municipality categories. As above, 95% confidence intervals were used, assuming a Poisson distribution.

Making use of both event and individual variables, we performed a cluster analysis by using multiple correspondence analysis (MCA) with agglomerative hierarchical clustering (AHC) to study common fire-related mortality typologies. In short, MCA with AHC is a generalization of standard multivariate cluster analysis techniques for categorical datasets and presents a way to effectively summarize and present a large set of variables into a much smaller set of principal components, or clusters (Husson, Lê & Pagès, 2010).

Since the clustering method requires that all data is at the same entity level, and one of the aims of this study was to describe common typologies of fire events, the individual data had to, in cases with more than one fatality (approximately 7% of the fires), be converted to the event level. For the age group variable this was accomplished by