Preventing accidental residential fires: the role of human involvement in non-injury house fires

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Abstract

Objective: Research to date has focused on causal descriptions of residential fire fatalities and injuries, with an emphasis on ignition factor. This paper examines if, how and why human actions or inactions lead to accidental residential fires and identifies risk factors most closely associated with those fires caused by human unsafe behaviours.

Methods: Interviews of 182 people who had survived accidental residential fires without serious injury were conducted. Each fire was classified as either 1) directly caused by human unsafe behaviours; 2) human long term inactions; or 3) involved NO human actions. Frequencies and odds ratio values were presented.

Results/Discussion: Slightly less than half (46%) of the non-injury fires were directly caused by human unsafe behaviours, 40% involved no human actions, and 14% were associated with long-term human inactions. Examination of the fires caused by human unsafe behaviours compared to no human involvement using Odds Ratios showed that individuals in the former group were significantly more likely to be mentally ill, physically disabled, asleep, not in full-time paid employment and more intimate with ignition.

Conclusions: Many non-injury fires do not directly arise from unsafe activity and most of them were caused by electrical or ignition system failure. New design innovations and/or improvements in appliances may reduce those fires due to appliance maintenance negligence or electrical faults. Identification of the most high risk individuals for unsafe behaviours can help inform fire safety educational programs.

Keywords: non-injury accidental residential fires, non-injured survivors, human involvement in fire ignition, risk factors

1. Introduction

Understanding the underlying causes of accidental residential fires is critical if we are to prevent fire deaths, injuries, and property damage, and attempt to reduce the frequency and severity of such accidents. Studies of accidental residential fire fatalities and injuries have revealed that cooking-related activities and electrical failure were the leading causes of fire injuries while smoking-related materials accounted for most fatalities, followed by combustibles too close to heat (Ahrens, 2013; Xiong et al., 2015). Most importantly, the majority of these fires have been caused by human errors or unsafe behaviours (Miller, 2005). Typical unsafe behaviours include unattended cooking, smoking while falling to sleep, placing a heater or candles too close to combustibles and a child playing with ignition sources. The research however, has so far focussed on a shallow description of the causes of residential fires, in other words, the ignition factors. Little work has been done in the areas of why and how these errors occurred and the underlying mechanisms associated with the causes are rarely investigated (Hall, 2012; Shea, 2011; U.S Fire Administration, 2007). Obviously this is often difficult to examine in fatal fires and any survivors may have little information about circumstances at ignition.

To help prevent accidental residential fires caused by human unsafe behaviours and to develop the most effective preventive intervention strategies, it is important to look at how and why humans get involved in fire ignition. Drawing upon interviews of individuals who have survived accidental residential fires without serious injuries involving extended hospitalization, this paper undertakes causal analyses of accidents to identify the kinds of human errors that have occurred in house fire settings. It examines the role of human involvement in fire ignition and explores the possible differences and similarities between non-injury house fires caused by human unsafe behaviours and fires where no human actions were involved. Such a deep exploratory analysis of the underlying circumstances of ignition and identification of those most at-risk of fires caused by human errors aims to provide new insights to inform preventive intervention strategies.

2. Methods

Data. Information concerning the fire incidents and contact details of potential interviewees were sourced from the daily records of fire incidents from the Victorian Metropolitan Fire Brigade (MFB, June 2010 to December 2011) and Country Fire Authority (CFA, January 2012 to June 2012), Australia. The potential interviewees were contacted when the fires met four selection criteria: 1) being residential (backyard/

frontyard fires were only included if they involved a structure such as a garage or shed); 2) being accidental (no cases where arson or serious criminal behaviour was suspected or proven were included); 3) no death or serious injury with extended hospitalisation involved; and 4) significant fire and/ or smoke damage to the room of fire origin and/ or dwelling.

In total, 196 interviews were conducted for this study, with one interview per fire. Of these 196 fires, information about 128 survivors was sourced from the MFB and 68 from the CFA. In terms of information obtained from the MFB, initially, approximately 53% of all fire incidents received from MFB met the above inclusion criteria, while 30% of the potential interviewees were not contactable by phone or letter. Decline rates were quite low at about 17%, and were mostly because the contacted interviewee indicated that he or she did not wish to be interviewed due to English language difficulties. CFA fires were handled slightly differently. A CFA Fire Officer examined the fire incidents attended by CFA for areas within about 200 km of Melbourne and contacted potential interviewees. They passed on the names and contact details of people from 153 fire incidents, who gave initial consent to being contacted by the researchers. Full interviews were obtained from 68 CFA fire incidents (44%).

Of the 196 interviews, nine were later excluded because of a large percentage of missing data concerning the person who was involved in the fire ignition. Of the 187 remaining fires, five incidents were known to have been caused directly by human actions, but it was impossible to determine who started the fire and thus these were also excluded. These five fires included three party fires caused by discarded cigarettes and two Halloween party fires caused by candles. Finally, information concerning 182 survivors of accidental residential fires was collected for the current analysis. This paper utilizes ‘host’ to refer to the person who was most closely involved in the fire start or, if this descriptor does not apply, to anyone was the person on the property who called the fire brigade at the time of fire.

In order to ensure the validity and reliability of the data, information concerning some key variables such as ignition factors was crosschecked between data drawn from interviews and the fire records filled by the fire brigade who attended the incident. Confidence codes (i.e., definite, most likely, possible, unknown) were used for a number of variables (i.e., ignition factors, involvement in fire ignition) to describe the degree of certainty regarding subjective judgements made by the coder, hosts and fire brigade. The confidence code of “definite” is given when information is clearly stated or decided by fire brigade, hosts or other survived occupants,

otherwise the judgement is coded as most likely, possible, or unknown. For the data analysis, if a confidence level for a variable was coded as either definitely or most likely, that variable was entered as being present for that host. On the basis of the fact that many variables are highly inter-related, the consistency between variables, across cases, and over time has been checked at the time of data analysis. Files that were coded at the earlier versus later stages were randomly selected, 10% respectively, to check whether fires have been coded in a similar manner, particularly those caused by similar ignition factors (i.e., unattended cooking). A different coder would revisit the case if necessary. Group discussions of potentially ambiguous coding issues were regularly undertaken to help ensure coding validity and reliability.

Analysis. Frequencies and percentages were used to describe the characteristics of survived accidental residential fires and survivors. Binary logistic regression (unadjusted odds ratios) was undertaken to explore the possible differences between fires caused by human unsafe behaviours and those where no human actions were involved. Odds ratio analysis was not applicable for fire agent factors due to the limited number of events available for the two categories. In cases with less than 5 events in a category, a Fisher's Exact Test was undertaken.

The methodology of this study was approved by the institution's Human Research Ethics Committee. It should be noted that there were a small proportion of fires caused by individuals who were less than 18 years of age or were suffering some mental illness at the time of the fire. In these cases parents or careers were interviewed instead, but information concerning the person who was involved in the fire ignition was collected.

3. Results

The result section comprises two parts. Part 1 investigates the role of human involvement in fire ignition (Table 1 and 2). Drawing upon odds ratio analyses (Table 3), Part 2 explores the possible differences between fires caused by human behaviours and those where no human actions were involved.

3.1. Human involvement in fire ignition

Based on the information collected from interview, particularly regarding ignition factors and human activities before fire and at the time of fire ignition, the non-injury accidental residential fires were grouped into three broad categories: fires directly caused by human unsafe behaviours, fires caused by human long-term inaction, and fires where no human direct actions/ inactions were involved. See Table 1 for further details and examples. Such classification may not cover all the circumstances that are associated with human involvement in fire ignition, but it provides a framework that can simplify the underlying complex circumstances surrounding the start of a fire from the perspective of human involvement in fire ignition.

Fires directly caused by human unsafe behaviours. Human unsafe behaviours accounted for just under half the examined fires (46%, Figure 1), with the time interval between unsafe behaviours and the occurrence of a fire being relatively small, normally within hours or concurrently. As shown in Table 2, cooking-related activities (45.2%), placing combustibles too close to heat (26.2%), and a child playing with ignition sources (14.3%) were the leading causes of non-injury accidental residential fires caused by human direct actions. Only five fires (6.0%) were caused by discarded cigarettes. No appliance was involved in the ignition for 31.7% of fires caused by human unsafe behaviours. When an appliance was involved, the stove predominated (71.2%), followed by heating unit (10.7%), portable cooker (7.1%) and lamp/ light globe (5.4%). One example for the latter is the fire caused by a boy who accidentally placed a blanket on top of a working lamp.

Of the 38 cooking-related fires (45.2% of the total fires caused by human unsafe behaviours), 29 were unattended cooking. Three hosts were individuals under 18 years of age. Other cooking-related scenarios include placing combustibles too close to heat (i.e., paper towel), careless cooking behaviours (i.e., food left burning in the rubbish bin or accidently spilling the water into the hot oil), cooking appliances (i.e., stove) unintentionally being turned on and not turned off or being turned on wrong way. Three fires were caused by the oven or microwave being turned on for too long, leading to the burning food materials. Similar scenarios appeared in three fires caused by wheat packs that were heated for too long in the microwave. A theme of ‘forgot’ and ‘distracted’ appeared in most interviews. Six interviewees reported that they left the property while cooking (i.e., picking up children, helping neighbours). Of the 22 fires caused by placing combustibles

too close to heat, five involved a heating unit, four were related to a working stove, three involved a working lamp/ light globe and ten were caused by a burning candle.

Human long-term inactions. Fires caused by human long-term inactions mainly refer to those caused by long term human negligence of maintenance/ cleaning of a household appliance. Behaviours associated *directly* with such fires are largely viewed as not in themselves unsafe. An example would be placing a chicken in an oven filled with a buildup grease and fat. The behaviour of 'placing a chicken in the oven' itself is normal and not unsafe. It is the lack of cleaning of built up grease and fat in the oven that causes the fire. Fourteen percent of all the fires studied in this paper fell into this category and nearly two thirds of these (64.0%) were caused by a lack of maintenance/ wearing out of a house appliance, with the remainder being from overloaded equipment (36.0%). All fires caused by long-term human negligence involved a household appliance. A little less than one third of such fires involved an extraction fan (30.4%), followed by heating unit (21.7%), electrical distribution equipment including cord and charger (21.7%), oven (13.1%) and dryer (13.1%).

No human actions involved. Many non-injury house fires (40%) were not caused by human actions, with faults in electrical or ignition systems accounting for the overwhelming majority (80.8%) of such fires. Fires caused by electrical failure include any mechanical failure/ fault/ malfunction detected or reported in electrical or ignition system, such as electrical distribution equipment (i.e., extension cords or plugs) or electronic equipment (i.e., TV, extraction fan, air conditioning unit). No appliance was involved in the ignition for 17.4% of all fires that fell into this category. When an appliance was involved, electrical distribution equipment (19.3%) was the most prevalent, followed by lamp/ light globe (12.3%) or air conditioning unit (10.5%). In some cases human activities might have been associated with this fire category but no causal relationship existed between the human behaviours and fire ignition. Such activities might be viewed as 'normal daily activities', rather than unsafe behaviours that may cause the fire. For example, a person turned on the walk-in wardrobe light, forgot to turn it off and a fire started after few hours. In this case, leaving the wardrobe light on is viewed as normal activity that should not pose a potential danger in daily life. It was an electrical fault with the wardrobe light that caused the fire.

3.2. Comparison between fires caused by human behaviours versus fires where no human actions were involved

The frequencies of the characteristics of non-injury house fires and survivors were categorized into four groups: the whole sample, fires caused directly by human unsafe behaviours, fires caused by human long-term inactions, and fires where no human actions being involved. Drawing on this frequency tabulation (see Appendix A), odds ratio analyses were undertaken to examine whether these differences were statistically significant between fires caused directly by human unsafe behaviours and those where no human actions were involved. As shown in Table 3, only 9 out of 23 variables tested were significant. In comparison with fires where there was no human involved, fires caused by human unsafe behaviours were more likely to be associated with, in descending OR value order: being in room of fire origin at the time of fire ignition (OR = 8.11), kitchen being the room of fire origin (OR = 7.16), mental illness (OR = 6.94), apartments/ units (OR = 4.84), afternoon and evening (OR = 3.83), physical illness (OR = 3.33), not likely to be in full time paid employment (OR = 2.93), property not owned by the interviewee (OR = 2.91), and being asleep (OR = 2.66).

4. Discussion

Consistent with the broad literature (Ahrens, 2013; McCormick, 2009; Miller, 2005), this study supports previous research finding that human errors/ unsafe behaviours are associated with many accidental residential fire incidents. By extending this body of research, with its shallow description of human errors being the cause of house fires, this study further investigated the mechanisms underlying the human errors by classifying non-injury accidental residential fires into three broad categories. These categories were based on the role of human involvement in fire ignition and compared possible differences across a wide range of factors. The three categories are: fires directly caused by human unsafe behaviours, long-term human inactions/ negligence, and no human actions involved. This is the first study to investigate house fires from the perspective of human involvement in fire ignition.

This paper found that nearly half (46%) of non-injury house fires were caused directly by human unsafe behaviours and nearly half of these fires were associated with cooking-related activities. This is consistent with previous studies that cooking-related activities/ equipment were the leading cause of accidental house fires and injuries (Ahrens, 2013; U.S Fire Administration, 2007), as well as fires handled without fire

department assistance (Diekman et al., 2012). Between 2007 and 2011, cooking equipment was the leading cause (38%) of fire injuries in the US (Ahrens, 2013). Similar trends were found in Canada, Australia, New Zealand and other countries (Australian Fire and Emergency Service Authorities Council, 2009; McCormick, 2009). Consistent with a report produced by U.S. Fire Administration (Fire Emergency Management Agency, 2003), this study found that unattended cooking equipment was the leading factor contributing to cooking fires. Unintentionally turning the equipment (i.e., cook-top, oven) on and forgetting to turn it off or turning it on over an extended time was also a significant determinant of cooking equipment-related house fires. Interlinked smoke alarms might be effective to alert residents to unattended cooking fires where they were asleep or not in the room of fire origin. However this in itself will not prevent the fires from occurring. The real challenge is that individuals may not perceive some dangerous habitual behaviours as being problematic enough to stop doing, even if they have previously had unsafe outcomes. Typical scenarios included leaving cooking materials unattended due to distraction by other things (i.e., chatting with other people, children), or even leaving the property (six cases in this study). Future studies might benefit from investigating underlying cognitive processes that support such risky actions in order to reduce fire incidents, deaths and injuries (Warda & Ballesteros, 2007). The inability of people to take responsibility for actions that affect their health and safety is the subject of considerable research within health psychology. Key models, such as the Theory of Planned Behaviour and Health Belief Model, suggest that attitude change is necessary before behavioural change can occur (Montanaro & Bryan, 2014; Pearson et al., 2012; Protogerou et al., 2012)..

One of the most important new findings is that 14% of non-injury house fires were associated with long-term human inactions/ negligence (i.e., a lack of maintenance or cleaning of a house appliance) where the human behaviours before and at the time of ignition can be viewed ‘normal/ not unsafe’ and the time intervals between human activities and fire ignition was days or even years. This study highlights the need for more monitoring of this type of fire. For fires caused by human long-term negligence, it is not easy to identify who may be responsible for the fire start, as household residents should share responsibilities to maintain a fire-safe environment. All such fires caused by long-term human negligence involved a household appliance where service or maintenance is expected to be undertaken on a regular basis in order to ensure safe operation. If maintenance was undertaken on a regular basis, many such fires could be prevented. In other cases, the fire may be related to an appliance not being used or maintained according to instructions. This includes

appliances that may overheat through having been in use beyond the recommended period of time for safe use. For example, electric blankets should be used only to warm the bed, should be switched off before getting in and be replaced after 10 years or sooner if excessively worn. Design features that warn people about the need for maintenance behaviours may be applicable for some appliances. For example a warning light could be incorporated into a dryer to indicate that it is time to check the lint filter after a predetermined number of uses. A warning sound (e.g. beeping alarm) could be incorporated into extraction fans before dirt, fuel and ignition sources accumulated exceed a safe amount. While improved regulatory standards or protocols might help improve safety in some cases, in many cases it is the human behaviour that needs changing. Some researchers believe that many fires are preventable if the human behaviour that brings the fuel and ignition source together can be altered (Barillo & Goode, 1996), while others (Miller, 2005) argue that dangerous habitual behaviours are not readily amenable to external scrutiny as individuals may not perceive these as being problematic. The current data suggests that some house fires may be preventable through new design features being invented and/or widely incorporated for appliances to warn people that fire-safe maintenance behaviours are required, such as extraction fans and dryers. Furthermore, fire services have a role to play in community education. Current programs that emphasise smoke alarm maintenance and testing could be extended to include regular maintenance of home appliances that feature in home fire ignition.

This is the first study to compare a wide range of factors between non-injury house fires caused directly by human unsafe behaviours and fires where no human actions were involved. No statistically significant differences were found between the two groups in terms of 14 characteristics associated with house fires, but the two types of fires did differ significantly in eight aspects. Fires caused by human unsafe behaviours were more likely to occur in the kitchen, apartments/ units, and during afternoon and evening time than fires where no human actions were involved. Individuals with the following characteristics (in descending order of importance) were most likely to be directly involved in fire ignition via their direct unsafe behaviours: those in the room of fire origin at the time of ignition, mentally ill, physically disabled, asleep, and not likely to be in a full time paid occupation. The customary explanation is that people who are mentally ill, physically disabled, asleep and not likely to be in a full time paid occupation (retired, disability pension, child) are less likely to have the same detecting, coping and life skills that the rest of the population utilise every day, and consequently, their actions and behaviours *during the fire* may reduce their ability to take a rational and

lifesaving approach (Watts-Hampton et al., 2006). Nonetheless, the findings of this paper suggest that it is the *involvement/ intimacy in fire ignition* that places these groups of people at high risk. People with some mental illness, physical disability/ illness and not likely to be in a full time paid occupation are the most vulnerable people in our community. The reduction of fire risks, injuries and deaths for these groups may need the collaboration of all stakeholders involving carers, fire services, council and community services. This paper suggests that to reduce the possibility/ chance of their involvement/ intimacy in fire ignition might be the first and most important step.

Some risk groups that are documented elsewhere to be highly related to fire fatalities and injuries were found not to be closely related to involvement in fire ignition in the current data. These include being male, being alone, being under the influence of alcohol and/or drugs and current smokers (Bruck et al., 2011; Buechner, 2003; Istre et al., 2001; Warda et al., 1999; Xiong et al., 2012, 2015). The present findings of less important relationships between these groups and their involvement in fire ignition arises partially from the fact that only a small proportion of people interviewed reported that they had engaged in associated risky behaviours, with most of them reporting to be awake and unimpaired at ignition. This finding, however, needs to be balanced with the possibility that those people who were heavily under the influence of alcohol or other substances at the time of their fire self-selected out of this study. However, these findings of different risk factors for people with no injuries compared to fire fatalities and injuries require replication with a larger, less self-selected sample.

Drawing on the information collected from national estimates of fires reported to U.S. municipal fire departments during 2007 – 2011, Ahrens (2013) found that electrical distribution and lighting equipment ranked third in house fires (6%), fourth in house fire deaths (13%), and fourth in house fire injuries (7%). This study on non-jury house fires in Australia however, revealed a much high rate. The current data shows that 40% of non-injury house fires were not caused by human actions or negligence and faults in electrical or ignition systems accounted for the overwhelming majority (80.8%) of such fires. Despite this difference from U.S. data, the present findings are consistent with some studies conducted elsewhere, such as Jakarta, Indonesia (Sufianto & Green, 2012) and Dubai (Alqassim & Daeid, 2014). Due to a lack of information concerning the failure/ faults in electrical equipment/ ignition system, it is hard to differentiate whether some electrical fires were caused by inappropriate installation of electrical equipment or by the shortcomings of

appliance design. However, that a significant proportion of fires were caused by electrical failure in the present data might suggest a need for continuous implementation of better quality and reliable electricity connection to buildings, an improvement in installation standards, and arc fault detection/protection and insulation monitoring to reduce residential fires (Shea, 2011; Sufianto & Green, 2012). In addition to improving building safety levels, residents should be trained to check and maintain electrical equipment and connections regularly, and most importantly to avoid overloading extension cords and to discard deteriorated wiring and cord sets.

Finally, discarded cigarettes or other smoking-related materials have been consistently identified as the leading cause of fatal house fires (Diekman et al., 2012; Hall, 2013); however, this study found that only 2.7% of non-injury house fires were caused by smoking-related materials. This difference in the leading cause of fatal and non-fatal/non-injury house fires is of great importance for fire research and prevention intervention strategies. Furthermore, 14.3% of fires caused by human unsafe behaviours were associated with a child playing with ignition sources, suggesting closer parent supervision and/ or child resistant lighters might be needed (Warda & Ballesteros, 2007)

5. Limitations

The present findings should be interpreted with caution. A relatively small number of survivors were interviewed and the interviewed sample may not represent the whole population that had experienced fire incidents at the time of survey. It is possible, for example, that more people from higher socio-demographic areas and less people from culturally and linguistically diverse backgrounds agreed to be interviewed. Because limited information was available from the MFB and CFA fire lists about the survivors, a comparison between people interviewed and those not contactable was not possible. Also, there are inherent methodological limitations associated with self-reported surveys because participants might seek to present themselves in a favourable manner (Thompson & Phua, 2005). Although multiple methods have been adopted in this study to ensure the validity and reliability of the data catergorisations, future studies are encouraged to adopt more advanced techniques, such as testing for a social desirability bias, to further ensure the reliability of the data (Podsakoff et al., 2003). This study focused on non-injury fires that occurred in Victoria, Australia, and results might not be generalisable to people who survived residential fires and lived in other cities where

demographic, socioeconomic, household and environmental structures and characteristics differ. Future studies are encouraged to examine the role of human involvement in non-injury house fires in other countries and to compare fires with death, major injuries, less serious injuries, and/or no injury. Finally, the current classification of human involvement in fire ignition should be viewed only as exploratory as there are many other ways in which human actions and errors can be defined and classified.

6. Conclusion

In sum, this is the first study that goes beyond the customary shallow characterisation of human error as a causal factor of accidental residential fires and examines the role of human involvement in fire ignition by considering both direct causal relationships and time intervals between human actions and fire ignition. Although the classification may not cover all circumstances surrounding fire ignition, it presents important new information about the role of human involvement in fire ignition and some of the factors behind the human errors that cause house fires. Part of the answer must be to alter human unsafe behaviours prior to fire ignition. Given that many fires caused by human unsafe behaviours included unattended cooking, interlinked smoke alarms might be effective. New design innovations and improvements in appliances may reduce those fires due to appliance maintenance negligence and faults.

Although eliminating fire incidents that stem from dangerous human behaviours may never be wholly effective, an increased understanding of the role of human involvement in fire ignition can help inform preventative and fire minimisation activities. These include how to design the most effective fire safety educational programs that target groups at high risk of involving in fire ignition and this study provides new information about those most at risk for non-injury fires. The messages that need to be conveyed are fairly simple, for example clean your extraction fans regularly, and could easily be added to existing community fire safety campaigns. The assumption here is that people will alter their behavior if they know that their current practice is unsafe. However it is also acknowledged that human behavior is a complex phenomenon and some people/actions are resistant to change.

The present classification of the three tiers of human involvement has been shown in this study to be a useful system and it could be used to examine changes over time, for example, and whether educational programs or design/technological improvements can help alter some of the risky human behaviours that cause

house fires. Further, understanding risk factors for accidental residential fires with uninjured survivors lays the foundation for subsequent comparisons with risk factors for fatal fires and fires with injuries to determine whether they are qualitatively different in terms of their risk factors or on a continuum.

7. What is already known on the subject

- Most accidental residential fires are caused by human errors
- Cooking and electrical failure cause most residential fire and injuries and smoking-related materials cause most fatal fires
- Some subgroups (the elderly, children, males, low SESs, alcohol and drug consumer, being asleep) are at high risk of fire fatalities and injuries

8. What this study adds

- Classification of accidental residential fires based on the role of human involvement in fire ignition
- To prevent or reduce fire incidents, the intervention in human unsafe behaviour in fire ignition could be an important strategy
- People who were mentally ill, physically disabled, asleep and not likely to be in a full time paid occupation (most retired, on disability pension, child) were more likely to be involved in fire ignition than their respective counterparts
- Fires with no human involvement accounted for four out of every ten non-injury fires.
- 14% of survived fires were associated with long-term human inactions/ negligence
- New design innovations in appliances with warning signals might be effective in preventing fires caused by human long-term negligence of maintenance

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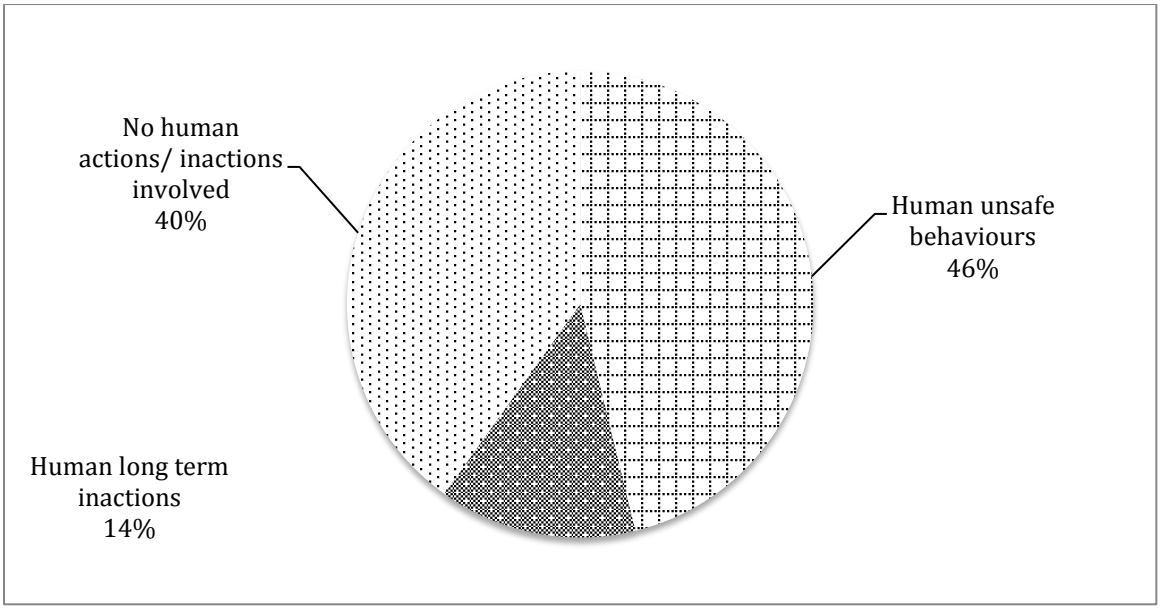

Figure 1 Survived accidental residential fires based on human involvement (n = 182)

Table 1. Human involvement in fire ignition classifications.

Human involvement		**Causes**	**Time interval between causes and fire**	**Human activity**	**Who was involved?**	**Examples**
Human involved	Short-term	Human direct actions	Simultaneously or within hours	unsafe	Person in direct contact with fire/ heat ignition sources	• leaving cooking materials (i.e., oil) unattended burning in the fry pan • placing burning candles or operating heater too close to combustibles
	Long-term	Human inactions	Relatively long, normally over days or years	normal	Household residents	• built up grease or fat in the oven • a lack of maintenance of extraction fan or cleaning of the dryer filter
No human involved		Other causes	Simultaneously or within hours, days or years	normal	No direct human involvement	• lightning • design fault

Table 2. Ignition factors and appliances involved, categorized into three groups: human involved (unsafe behaviour, inactions), and no human involved in the fire ignition

	Human involved % within column (n)		No human involved	Total
	Unsafe behaviour	Inactions	% within column (n)	% of Total (n)
Ignition factors (n=182)				
• Failure/ faults in electrical or ignition system	0	0	76.5 (56)	30.8 (56)
• Unattended cooking	34.5 (29)	0	0	15.9 (29)
• Combustibles too close to heat	26.2 (22)	0	4.1 (3)	13.7 (25)
• Lack of maintenance/ worn out	0	64.0 (16)	0	8.8 (16)
• Child playing with ignition sources	14.3 (12)	0	0	6.6 (12)
• Cooking other	10.7 (9)	0	0	4.9 (9)
• Overloaded equipment	0	36.0 (9)	0	4.9 (9)
• Discarded cigarettes	6.0 (5)	0	0	2.7 (5)
• Improper start up/ shut down	3.6 (3)	0	0	1.6 (3)
• Others[a]	3.6 (3)	0	5.5 (4)	3.8 (7)
• Undetermined	1.1 (1)	0	13.6 (10)	6.3 (11)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Appliances involved				
• Stove	48.8 (40)	0	1.5 (1)	23.6 (41)
• Heating unit (i.e., central, fixed, portable, indoor fireplace)	7.3 (6)	21.7 (5)	7.2 (5)	9.2 (16)
• Electrical distribution equipment, fixed wiring, cord, plug, charger	1.2 (1)	21.7 (5)	16.0 (11)	9.8 (17)
• Extraction fan	0	30.4 (7)	5.8 (4)	6.3 (11)
• Lamp/ light globe	3.7 (3)	0	10.1 (7)	5.7 (10)
• Portable cooker	4.9 (4)	0	4.3 (3)	4.0 (7)
• Oven	1.2 (1)	13.1 (3)	1.5 (1)	2.9 (5)
• Air conditioning unit	0	0	8.7 (6)	3.4 (6)
• TV	0	0	5.8 (4)	2.3 (4)
• Dryer	0	13.1 (3)	0	1.7 (3)
• Dishwasher	0	0	5.8 (4)	2.3 (4)
• Others [b]	1.2 (1)	0	16.0 (11)	6.9 (12)
Total % of column (% of total, n)	68.3 (32.2, 56)	100.0 (13.2, 23)	82.7 (32.8, 57)	78.2 (136)
• No appliance involved	31.7 (26)	0	17.3 (12)	21.8 (38)
Total	100.0 (82)	100.0 (23)	100.0 (69)	100.0 (174)

Note. [a] includes lightening, collision, open fire, and design faults. [b] others includes portable refrigeration unit, separator motor, hand tools, household appliances not specified, and motor vehicle.

Table 3. Unadjusted odds ratio (OR) analysis results for non-injury accidental residential fires caused by human unsafe behaviours versus fires where no human actions were involved in fire ignition, in descending OR order.

	Human unsafe behaviour % (*n*)	No human involved % (*n*)	OR	95% CI
Location at ignition (*n*=156)				
In RFO	37.3 (31)	6.8 (5)	8.11***	2.95, 22.29
Not in RFO	62.7 (52)	93.2 (68)		
Kitchen being RFO (*n*=182)				
Kitchen	56.0 (47)	15.1 (11)	7.16***	3.31, 15.50
Other	44.0 (37)	84.9 (62)		
Mental illness (*n*=141)				
Yes	29.0 (20)	5.6 (4)	6.94***	2.23, 21.58
No	71.0 (49)	94.4 (68)		
Type of occupancy (*n*=142)				
Apartment/ unit	19.2 (15)	4.7 (3)	4.84**	1.34, 17.56
One or two family dwelling	80.8 (63)	95.3 (61)		
Time of a day (*n*=102)				
Afternoon & evening	75.8 (47)	45.0 (18)	3.83**	1.63, 8.98
Other	24.2 (15)	55.0 (22)		
Physical illness (*n*=139)				
Yes	23.5 (16)	8.5 (6)	3.33*	1.22, 9.12
No	76.5 (52)	91.5 (65)		
Occupation (*n*=138)				
Not likely to be full time paid	57.4 (39)	31.4 (22)	2.93**	1.46, 5.89
Likely to be full time paid	42.6 (29)	68.6 (48)		
Property ownership (*n*=182)				
Other	45.2 (38)	22.0 (16)	2.91***	1.47, 5.77
Owned by interviewee	54.8 (46)	78.0 (57)		
Asleep (*n*=131)				
No	83.6 (51)	65.7 (46)	2.66*	1.15, 6.15
Yes	16.4 (10)	34.3 (24)		
Pre-existing other disability (*n*=140)				
Yes	13.2 (9)	4.2 (3)	3.51	0.91, 13.56
No	86.8 (59)	95.8 (69)		
Living arrangement (*n*=153)				
With family/ others	86.4 (70)	94.4 (68)	2.67	0.81, 8.80
Alone	13.6 (11)	5.6 (4)		
Internal state of a dwelling (*n*=118)				
Clean & tidy	71.7 (43)	85.4 (35)	2.31	0.82, 6.47
Moderately cluttered	28.3 (17)	14.6 (6)		
Season of a year (*n*=157)				
Other seasons	82.1 (69)	69.9 (51)	1.98	0.94, 4.20
Summer (Dec., Jan., Feb.)	17.9 (15)	30.1 (22)		
Bedroom being RFO (*n*=182)				
Bedroom	21.4 (18)	12.3 (9)	1.94	0.81, 4.63
Other	78.6 (66)	87.7 (64)		
External condition to a building (*n*=105)				
Good overall condition	93.1(54)	89.4 (42)	1.61	0.41, 6.36

State of disrepair	6.9 (4)	10.6 (5)		
Previous fire experience (*n*=128)				
Yes	79.7 (47)	84.1 (58)	1.34	0.55, 3.33
No	20.3 (12)	15.9 (11)		
Country origin (*n*=91)				
Overseas	37.3 (25)	30.9 (21)	1.33	0.65, 2.72
Australia	62.7 (42)	69.1 (47)		
Fire safe knowledge (*n*=152)				
No or basic/ general knowledge	73.0 (46)	77.6 (52)	1.28	0.58, 2.85
Some specific learning	27.0 (17)	22.44 (15)		
Age (*n*=136)				
18 – 59 years of age	83.1 (54)	80.3 (57)	1.21	0.50, 2.89
60 +	16.9 (11)	19.7 (14)		
Sex (*n*=157)				
Male	48.8 (41)	46.6 (34)	1.09	0.58, 2.05
Female	51.2 (43)	53.4 (39)		
Alcohol use (*n*=131)				
Yes	13.8 (9)	10.6 (7)	1.36	0.47, 3.88
No	86.2 (56)	89.4 (59)		
Current smoker (*n*=149)				
Yes	28.9 (22)	23.3 (17)	1.34	0.64, 2.78
No	71.1 (54)	76.7 (56)		
Drug use (*n*=131)				
Yes	4.6 (3)	0	N/A	
No	95.4 (62)	100.0 (66)		

Note. $^{***}p<0.001$. $^{**}p<0.01$. $^{*}p<0.05$. N/A indicates not applicable.

11. Appendix

Appendix A. Characteristics of survived accidental residential fires, categorized into three groups: human involved (unsafe behaviour, inactions), and no human involved in the fire ignition

	Human involved % within column (n)		No human involved % within column (n)	Total % of Total (n)
	Unsafe behaviour	Inactions		
Room of fire origin				
Kitchen	56.0 (47)	16.0 (4)	15.1 (11)	34.1 (62)
Bedroom	21.4 (18)	12.0 (3)	12.3 (9)	16.5 (30)
Ceiling/ roof space	1.2 (1)	8.0 (2)	19.2 (14)	9.3 (17)
Toilet/ bathroom	2.4 (2)	24.0 (6)	8.2 (6)	7.7 (14)
Garage	4.8 (4)	0	11.0 (8)	6.6 (12)
Lounge room	4.8 (4)	8.0 (2)	5.5 (4)	5.5 (10)
Laundry	0	12.0 (3)	4.1 (3)	3.3 (6)
Tool shed	3.6 (3)	4.0 (1)	6.8 (5)	4.9 (9)
Others [d]	5.8 (5)	16.0 (4)	17.8 (13)	12.2 (22)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Type of occupancy				
One or two family dwelling	75.0 (63)	88.0 (22)	83.6 (61)	80.2 (146)
Apartment/ unit	17.9 (15)	8.0 (2)	4.1 (3)	11.0 (20)
Tool shed	3.6 (3)	4.0 (1)	9.6 (7)	6.0 (11)
Parking garage	1.2 (1)	0	2.7 (2)	1.7 (3)
Bungalow	2.4 (2)	0	0	1.1 (2)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Time of a day				
Night (24:00 – 05:59)	11.3 (7)	15.4 (2)	25.0 (10)	16.5 (19)
Morning (6:00 – 11:59)	12.9 (8)	15.4 (2)	30.0 (12)	19.1 (22)
Afternoon (12:00 – 17:59)	45.2 (28)	30.8 (4)	17.5 (7)	33.9 (39)
Evening (18:00 – 23: 59)	30.6 (19)	38.5 (5)	27.5 (11)	30.4 (35)
Total	100.0 (62)	100.0 (13)	100.0 (40)	100.0 (115)
Property ownership (*n*=182)				
Owned by interviewee	54.8 (46)	60.0 (15)	78.0 (57)	64.8 (118)
Rented	35.7 (30)	32.0 (8)	17.8 (13)	28.0 (51)
Public housing	7.1 (6)	8.0 (2)	2.7 (2)	5.5 (10)
Others [b]	2.4 (2)	0	1.4 (1)	1.7 (3)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Internal state of a dwelling				
Clean & tidy	71.7 (43)	88.2 (15)	85.4 (35)	78.8 (93)
Moderately cluttered	28.3 (17)	11.8 (2)	7.3 (3)	18.6 (22)
Severely cluttered	0	0	7.3 (3)	2.5 (3)
Total	100.0 (60)	100.0 (17)	100.0 (41)	100.0 (118)
Season of a year				
Spring (Sep., Oct., Nov.)	26.2 (22)	32.0 (8)	21.9 (16)	25.3 (46)
Summer (Dec., Jan., Feb.)	17.9 (15)	20.0 (5)	30.1 (22)	23.1 (42)
Autumn (March, April, May)	27.4 (23)	32.0 (8)	26.0 (19)	27.5 (50)
Winter (June, July, August)	28.6 (24)	16.0 (4)	21.9 (16)	24.2 (44)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)

External condition to a building				
Good overall condition	93.1(54)	100.0 (18)	89.4 (42)	92.7 (114)
State of disrepair	6.9 (4)	0	10.6 (5)	7.3 (9)
Total	100.0 (58)	100.0 (18)	100.0 (47)	100.0 (123)
Age				
< 18 years of age	20.2 (17)	0	1.4 (1)	9.9 (18)
18 – 69 years of age	66.7 (56)	76.0 (19)	79.5 (58)	73.1 (133)
70 +	13.1 (11)	24.0 (6)	19.1 (14)	17.0 (31)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Sex				
Male	48.8 (41)	36.0 (9)	46.6 (34)	46.2 (84)
Female	51.2 (43)	64.0 (16)	53.4 (39)	53.8 (98)
Total	100.0 (84)	100.0 (25)	100.0 (73)	100.0 (182)
Living arrangement				
With family	77.8 (63)	88.0 (22)	87.5 (63)	83.1 (148)
With others	8.6 (7)	0	6.9 (5)	6.7 (12)
Alone	13.6 (11)	12.0 (3)	5.6 (4)	10.2 (18)
Total	100.0 (81)	100.0 (25)	100.0 (72)	100.0 (178)
Country origin				
Australia	62.7 (42)	79.2 (19)	69.1 (47)	67.9 (108)
Overseas	37.3 (25)	20.8 (5)	30.9 (21)	32.1 (51)
Total	100.0 (67)	100.0 (24)	100.0 (68)	100.0 (159)
Occupation				
Type A	6.8 (5)	0	14.3 (10)	8.9 (15)
Type B	9.5 (7)	13.0 (3)	21.4 (15)	14.9 (25)
Type C	12.2 (9)	30.4 (7)	20.0 (15)	18.5 (31)
Type D	10.8 (8)	0	12.9 (9)	10.1 (17)
Stay home parent/home maker	10.8 (8)	17.4 (4)	12.9 (9)	12.5 (21)
Student	21.6 (16)	4.3 (1)	4.3 (3)	11.9 (20)
Sickness benefits / disability pension	14.9 (11)	13.0 (3)	2.9 (2)	9.5 (16)
Retired	2.7 (2)	17.4 (4)	7.1 (5)	6.5 (11)
Unemployed	2.7 (2)	4.3 (1)	4.3 (3)	3.6 (6)
Child	8.1 (6)	0	0	3.6 (6)
Total	100.0 (74)	100.0 (23)	100.0 (71)	100.0 (168)
Previous fire experience				
Yes	79.7 (47)	79.2 (9)	84.1 (58)	81.6 (124)
No	20.3 (12)	20.8 (5)	15.9 (11)	18.4 (28)
Total	100.0 (59)	100.0 (24)	100.0 (69)	100.0 (152)
Fire safe knowledge				
No pre-existing knowledge	6.3 (4)	13.6 (3)	6.0 (4)	7.2 (11)
Basic/ general knowledge	66.7 (42)	72.7 (6)	71.6 (48)	69.8 (106)
Some specific learning	23.8 (15)	13.6 (3)	22.4 (15)	21.7 (33)
Technical/ formal training	3.2 (2)	0	0	1.3 (2)
Total	100.0 (63)	100.0 (22)	100.0 (67)	100.0 (152)
Location at ignition (n=181)				
In RFO	37.3 (31)	4.0 (1)	6.8 (5)	20.4 (37)
Not in RFO	62.7 (52)	96.0 (24)	93.2 (68)	79.6 (144)
Total	100.0 (83)	100.0 (25)	100.0 (73)	100.0 (181)
Mental illness				
Yes	29.0 (20)	12.5 (3)	5.6 (4)	16.4 (27)
No	71.0 (49)	87.5 (21)	94.4 (68)	83.6 (138)
Total	100.0 (69)	100.0 (24)	100.0 (72)	100.0 (165)

Physical illness				
Yes	23.5 (16)	12.0 (3)	8.5 (6)	15.2 (25)
No	76.5 (52)	88.0 (22)	91.5 (65)	84.8 (139)
Total	100.0 (68)	100.0 (25)	100.0 (71)	100.0 (164)
Pre-existing other disability				
Yes	13.2 (9)	8.0 (2)	4.2 (3)	8.5 (14)
No	86.8 (59)	92.0 (23)	95.8 (69)	91.5 (151)
Total	100.0 (68)	100.0 (25)	100.0 (72)	100.0 (165)
Asleep				
Yes	16.4 (10)	31.8 (7)	34.3 (24)	26.8 (41)
No (awake & unimpaired)	83.6 (51)	68.2 (15)	65.7 (46)	73.2 (112)
Total	100.0 (61)	100.0 (22)	100.0 (70)	100.0 (153)
Alcohol use				
Yes	13.8 (9)	4.2 (1)	10.6 (7)	11.0 (17)
No	86.2 (56)	95.8 (23)	89.4 (59)	88.0 (138)
Total	100.0 (65)	100.0 (24)	100.0 (66)	100.0 (155)
Current smoker				
Yes	28.9 (22)	24.0 (6)	23.3 (17)	25.9 (45)
No	71.1 (54)	76.0 (19)	76.7 (56)	74.1 (129)
Total	100.0 (76)	100.0 (25)	100.0 (73)	100.0 (174)
Drug use				
Yes	4.6 (3)	0	0	4.6 (3)
No	95.4 (62)	100.0 (24)	100.0 (66)	95.4 (152)
Total	100.0 (65)	100.0 (24)	100.0 (66)	100.0 (155)

[d] includes spa room, dining room, study room, rubbish area, under house, carport, wall surface, backyard/ front yard. [b] includes visitors. Type A includes senior management and professionals. Type B includes managers and associate professionals. Type C includes trades persons, clerks, skilled office and sales. Type D includes - machine operators, hospitality, assistants, and labourers.