Fire and at risk populations in Canada

Analysis of the Canadian National Fire Information Database

Dr Joe Clare and Ms Hannah Kelly

December 2017

UNIVERSITY OF THE FRASER VALLEY
CENTRE FOR PUBLIC SAFETY & CRIMINAL JUSTICE RESEARCH

Murdoch UNIVERSITY

Table of Contents

Executive Summary

1. This research examines the Canadian National Fire Information Database (NFID) to understand more about At Risk Populations (Area of Focus #5 as per the Request for Proposal documentation). The broad focus was to explore what we know about fire-related casualties in Canada and what the protective influences of working life safety systems are. The analysis focused on residential structure fires reported to the NFID between 2005 and 2015, reported by Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan. With a focus on non-firefighter casualties, the sample of residential fires included 830 deaths and 4,656 injuries

2. Prior research indicates: (a) elevated risk for older residents (65 years and over), children under 5 years, and Indigenous populations, (b) present, functioning life safety systems also reduce the likelihood of deaths from residential fires, and (c) houses that experience residential fires are less likely to have working life safety systems in place.

3. There was approximately 7,130 residential fires per year with an average injury rate of 70.8 injuries per 1,000 fires and an average death rate of 10.9 deaths per 1,000 fires.

4. Fire-related deaths and injuries were more likely to involve males and older residents were much more likely to have died in fires (relative risk of 65 to 79 year olds dying 1.6 times above the population rate and 80 years and over 2.4 times greater than the population overall).

5. Almost one-third of fatalities were asleep at the time of fire, 31% were impaired by alcohol, drugs, or medication, and 21% were awake with no physical/mental impairments. Almost two-thirds of injuries involved a casualty who was awake with no physical/mental impairments at the time of the fire and one-quarter were asleep at the time of the fire.

6. Approximately half of deaths resulted from rapidly spreading fire/smoke, 14% resulted from high flame spread of combustible interior finish, and only 7% of the known reasons for failure to escape were as a result of age and/or other physical limitations.

7. About one-third of non-firefighter fatalities occurred while the casualty was attempting to escape, 29% did not act, and 14% experienced a loss of judgement or panic. Half of the cases resulting in injury involved the person entering/remaining for rescue, firefighting, or saving personal property.

8. Residential fires that were contained to the room of origin (44%) resulted in 57% of injuries and 24% of deaths, at a rate of 79.2 injuries and 3.8 deaths per 1,000 fires. In comparison, fires that extended beyond the room and (as far as beyond the property of origin, 22%) resulted in 28% of injuries and 59% of deaths (75.9 injuries and 28.4 deaths per 1,000 fires, respectively).

9. Residential fires that required fire department intervention (37%) resulted in 34% of injuries and 63% of deaths (at a rate of 18.5 deaths per 1,000 fires). In comparison, when fires were extinguished using hand held extinguishers or makeshift firefighting aids (17.0% of fires) there was a death rate of 1.7 per 1,000 fires.

10. Across the period of analysis the average rate of activation of working smoke alarms was 309.4 per 1,000 fires (with 2015 figures noticeably below this). There has also been a steady year-on-year increase in the presence of sprinkler protection in residential buildings, increasing to 72.5 per 1,000 fires in 2015.

11. Relatively few residential fires (4%) had complete sprinkler protection and two-thirds of these fires had no sprinklers. Comparing between these two groups, death and injury rates were much lower in the presence of complete sprinkler protection (1.3 deaths per 1,000 fires, compared to 11.3 deaths per 1,000 fires with no sprinkler protection).

12. The relative death rates per 1,000 fires was significantly lower for the 31% of fires when the smoke alarm was activated (6.8 per 1,000 fires), compared to fires where the alarm was not activated or was not installed (14.1 and 10.2 per 1,000 fires, respectively). As with previous research, the injury rate was highest in the presence of a working smoke alarm: consistent with casualties fighting fires.

13. When aggregating fire safety system presence and looking at fire outcomes, the following main findings were produced:
    a. Just over two-thirds of these residential fires had no present, functioning life-safety systems and these fires resulted in 80% of the deaths in this sample.
    b. Relative to fires with no life safety systems in place, fires with either a working smoke alarm or complete sprinkler protection are much less likely to result in a death, less likely to require fire department intervention, and less likely to extend beyond the room of origin.
    c. The compound effect of both sprinkler protection and a working smoke alarm resulted in only 4 deaths, required the least amount of fire department intervention, and the fires did not extend beyond the room of origin 94% of the time.

14. These findings are consistent with previous research and should be used to implement targeted fire prevention campaigns, building on Census data to identify at-risk populations. Given the aging population in Canada and the elevated risk of fatality for older citizens in the event of residential fires, this should be a priority for the Canadian emergency first responders and governments into the future. Based on these findings, the researchers urge the Canadian fire service to adopt a proactive, partnership-based, prevention focus to maximise the potential for elderly residents to remain living safely in their own homes for longer. In addition to targeting preventable fires, this initiative could also attempt to reduce the risks of trips/falls and crime victimisation. Given the consistency of findings relating to the elevated risk for this sub-section of the population, it is unacceptable to fail to act.

Research aim

This report summarises an analysis of the Canadian National Fire Information Database (NFID) to understand more about **At Risk Populations** (Area of Focus #5 as per the Request for Proposal documentation). In broad terms this research examines the extent to which the NFID can give additional insight into the uneven distribution of risk for fire across the Canadian population. The specific research questions that this research explores are:

1. What do we know about casualties (injuries and deaths) that have resulted from residential fires in Canada? This will focus on examination of:
    a. The demographic characteristics of casualties.
    b. What is known about the behavior of individuals who became fire casualties?
    c. What is known about the fires that led to these casualties?

2. What is the protective influence of working fire safety systems (smoke alarms and sprinkler systems)?
    a. What is the coverage of these life safety systems nationally?
    b. What are the longitudinal trends with respect to coverage of these life safety systems?
    c. How do fire-related casualties vary as a consequence of coverage of these life safety systems?

The answer to these questions will directly impact policy and practice decision making processes for the delivery of fire prevention services across Canada. Best-practice research clearly indicates that fire risk is unevenly distributed across time, space and individuals. Further to this, targeted prevention is possible, when founded on appropriate evidence-based analysis. This research will provide much-needed insight into the non-random distribution of risk across Canada. This knowledge will better-arm the fire service to proactively reduce fire risks for at risk populations, working in a targeted, prevention-focused, sustainable manner.

What do we know already? A short summary of relevant literature

This section of the report briefly summarizes what is already known about populations who are at risk from residential fire. Fires that occur in residential buildings are the leading cause of fire-related death and injury [1]. In 2007, 42,753 fires occurred in Canada resulting in the deaths of 224 civilians [2]. Thirty percent of these fires occurred in residential structures yet they accounted for 73% of deaths. Similarly, in the United States of America (U.S.), residential fires represented 28.6% of fires overall and caused 78% of deaths and 71% of injuries, in 2015 [3]. Not all residential fires are fatal, or require fire department intervention, yet various risk factors exist that, when present, can increase the likelihood of fire-related death or injury. Indeed, research has found significant differences among fatal and survived house fires [4]. In broad terms, it is important to understand the significance of individual characteristics, household characteristics, and area characteristics for their

influence on residential fire outcomes. These outcomes are also mediated by the presence of functioning life safety systems such as smoke alarms and residential sprinklers.

AT-RISK POPULATIONS

Men, older adults (65+ years), children under 5 years, and Indigenous populations are over-represented among residential fire casualties [5]. Men are consistently more likely to die or become injured in a house fire than women [6]. This could be because men are more likely to be under the influence of drugs or alcohol and engaged in dangerous behaviors such as trying to fight the fire and attempting a rescue, when injured [1, 7]. Older adults, children and Indigenous communities are at increased risk for a number of reasons; further discussed below.

Older adults (aged 65 and over)

In the U.S., more than 1,000 older adults die in residential fires each year and another 2,000 are injured [6]. Internationally, older adults are consistently at greater risk of fire-related death than any other age group and the risk increases with age [8-12]. Indeed, research has found that for adults aged 65-74 years the relative risk of dying in a residential fire is 1.9 times higher than the general population and 4.6 times higher for those aged over 84 years [11]. Almost one-third of home fire victims are aged 65 years and over, yet this demographic only represent 13% of the American population [11].

Carelessly or inappropriately discarded smoking materials are the leading cause of ignition in fatal residential fires, especially those with elderly victims [1]. From 2007-2011 in the U.S., 46% of residential fire fatalities caused by smoking materials, were aged 65 years or older [1]. Fatal fires caused by heating units were also prevalent among this population with older adults accounting for 38% of these deaths. Holborn et al. [8] found that a significant number of house fire deaths among this demographic involved the ignition of clothing, followed by bed linens and upholstered furniture. When ignited, these materials could be more likely to result in fatality as it is possible they would be in close proximity to the victim. Almost half of elderly victims were located in the bedroom when injured (fatally and non-fatally) [6].

Older adults are at increased risk of casualty for a number of reasons. First, health declines with age and as a result the elderly are more likely than the general population to suffer from diminished sensory ability, mobility and mental capacity disorders. Secondly, the elderly are more likely to live below the poverty line which in itself creates a number of additional risk factors for casualty. Diminished sensory ability is a normal part of the ageing process, yet it also leads to increased risk in cases of fire [6]. According to the U.S. Fire Administration (2013a), a decrease in two or more of the senses can lead to a substantial increase in risk of fire-related casualty.

- **Vision.** Sight arguably plays the most important role in fire safety. Individuals with poor/no vision are less likely to notice when combustibles are placed too close to a heat source or smoking materials are not discarded correctly [6]. Diminished vision may also increase the risk of older adults falling on top of heating units or falling during escape, further increasing the risk of casualty.

- **Sound.** As mentioned above, many fire-related deaths occur when people are asleep, yet having a working smoke alarm can significantly reduce the risk of casualty. In fact, the auditory system is the only sensory system that remains active while an individual is asleep [13]. However, one in three older adults suffers from hearing loss and the number increases with age [14]. Age-related hearing loss most commonly affects an individuals' ability to hear high-pitched noises and the average residential smoke alarm emits a high-frequency signal [15]. Research has found that people with mild to moderately severe hearing loss are less likely to respond to the average residential smoke alarm when sleeping [16, 17], leaving a large proportion of older adults at greater risk during this time.
- **Touch.** As people age they experience changes in their skin (such as thinning and wrinkling), because of this older adults can experience a diminished sense of touch [18]. Higher tactile thresholds can mean that older adults have trouble sensing heat or pain and have slower reaction to various stimuli [18]. Changes such as these could lead to an increase in burn severity, as during a fire, grabbing a hold of something (such as a door handle) could cause serious damage to the skin, especially when the individual does not immediately notice/react to the heat.
- **Smell.** Along with sight, olfaction can aid us in quickly determining the presence of a fire. However, research has found that smell is not consistently capable of waking people from a deep sleep [19, 20]. As mentioned above, many victims of house fires are overcome whilst asleep. Indeed, from 2007-2011, 40% of fatalities died from smoke inhalation alone, in the U.S. [1]. Considering smell is unlikely to wake people from sleep in general and olfaction decreases with age, the chances of older adults waking from the smell of smoke alone are presumably even less than the general population.

Older adults are also likely to suffer from physical disabilities that restrict their ability to fulfil daily activities. In fact, 38.7% of older Americans reported having at least one physical or mental disability, with the most common being; serious difficulty walking or climbing stairs [21]. Research has found that people with physical disabilities/limited mobility are at greater risk of dying in residential fires [22]. Not only could limited mobility/physical disability limit a person's reaction time and their ability to escape, but they may also be unable to adequately install/maintain smoke alarms within their homes [23].

The elevated likelihood of an elderly person dying in the event of a residential fire is also influenced by incidents of diminished mental capacity in this cohort. In the U.S., 9% of men and 11% of women aged 65 years and over living among the public have a diagnosis of dementia [24]. Dementia, as well as other forms of severe decrease in mental capacity, can lead to an increased risk of fire-related casualty [11, 12]. As well as a possible reduction in reaction time, diminished mental abilities can lead to an increased likelihood of engaging in dangerous fire-related behaviors [11, 12]. They may also be less likely to recognize a hazard or comprehend the need to escape in certain situations.

Finally, the elevated risk for elderly residents is also influenced by characteristics of the living arrangements for this group. According to FIFARS (2016), in the U.S., 36% of women and 20% of men over the age of 65 years live alone and 39% of older American adults reported having housing problems. Furthermore, as the majority of older adults are not actively participating in the labor

force, many rely on social security/retirement savings as their main form of income [24]. Ten percent of older adults in the U.S. live below the poverty line and 23% on a low income (FIFARS, 2016). People aged 65 years and over living below the poverty line are also twice as likely to smoke cigarettes [24] and households with at least one regular smoker are at greater risk of residential fire injury and less likely to have a working smoke alarm [25, 26]. In combination across these research findings, older adults that live alone are less likely to have working smoke alarms in their homes and are at increased risk of fire-related death [4, 27]. This relative disadvantage is also likely linked to the findings from Coty et al.'s [23] research, in which many of the participants (older adults) relied on free smoke alarm distribution from local fire departments.

Young Children (aged 5 and under)

In the past, along with older adults, young children have been over-represented among house fire casualties [28]. Fire-related death and injury among children under 15 decreases with age, with children under the age of 5 years accounting for the highest fire-related child deaths and injuries (Ahrens, 2014). However, research has found that the risk of fire-related casualty among young children has steadily been decreasing [1]. From 1980-2011, in the U.S., the percentage of home fire fatalities aged 5 years and under dropped from 18% down to 6%. Indeed, the U.S. Fire Administration's [12] study concluded that the relative risk for young children dying in a house fire was 10% less than the general population, in 2010. This decrease in child fire-related casualties is believed to be attributed to the introduction of child-resistant lighters in 1994 [1]. Yet, even though young children are now at less risk, they still remain vulnerable compared to older children as they are less likely to be able to understand the need to act quickly in certain situations and escape without the help of another [1].

Fire-play (or playing with a heat source) is the leading cause of fire-related death among children [1]. In fact, 80% of the people killed and 40% injured by house fires caused by fire-play were under the age of 15. Furthermore, 61% of these deaths were children aged 5 and under. It is important to note however, that child fatalities of fire-play are not always directly involved in the ignition. In their study of child victims of fire-play, Harpur et al. [29] found that the fatalities under the age of 2 years were the result of fire-play by an older sibling in the house. Matches and lighters were the most commonly cited sources of ignition in fires that resulted in child casualty [30, 31]. Fires caused by fire-play can spread out of control very quickly, especially in instances where bed linens or clothing were ignited [29]. As most children are directly involved with the ignition, many are injured/die from burns rather than smoke inhalation [29], which is the most common cause of residential fire-related casualty in general [1]. Indeed, in Harpur et al.'s [29] study 86% of children were located in the room of fire origin at the time of ignition, a significant risk factor in fatal fires. Most fires caused by fire-play also began in the bedroom or lounge room, another significant risk factor. Besides the risk factors associated with fire cause and location among this population, various household characteristics that increase risk also exist.

Risk factors for child fire-related casualty often depend on the child's home and family environment. Single parent, low SES households, the presence of a regular smoker and inadequate supervision are all major risk factors for child fire-related fatality [12, 29]. Single parent families are more likely to live below the poverty line or in low income households [32]. Low SES households already present a

certain number of risks (as mentioned above for the elderly), however, low SES, single parent households are at additional risk. Single parents often rely on a sole income and are less likely to have access to child care services and as a result, may be unable to adequately supervise their children at all times. As the majority of child fire-related casualties are due to fire-play, supervision of the child could have a substantial impact on the probability of a fire occurring. Indeed, research has found that fire-play often occurs in the absence of a guardian or in the presence of a guardian that is incapable of preventing the fire (in another room/not in close enough proximity to prevent injury or incapacitated by drugs or alcohol) [22, 33].

Indigenous Populations

Internationally, Indigenous populations have consistently higher risk for fire-related casualty than Caucasian people. In New Zealand, Māori people are three times more likely to die in a residential fire than the general population [10]. First Nation's citizens in British Columbia, Canada, were also at greater risk, with statistics showing higher risk among every age group [34]. Overall, the risk of fire-related fatality for First Nation's people in British Columbia was 9.4 times higher than the general population. In the U.S., African Americans account for 13.3% of the overall population [35], yet they are twice as likely to die in a residential fire, with the highest death rates among young children and older adults [1]. Compared to Caucasian children (aged 0-4), African American children had 2.4 times higher risk of fatality [11]. Indeed, 29% of child fire-related deaths were African American. Much like the general older population, the risk of house fire casualty increases with age among the older African American population [6]. However, the increase in risk occurs at a substantially higher rate. Male African Americans aged 85 and over have the highest relative risk of house fire fatality than any other group in the U.S.; more than 19 times the risk of the general population and 4 times the general elderly population [11]. It is likely that Indigenous people are more likely to be at increased risk as they are more likely to live below the poverty line or on a low income. In America, both African American and American Indian populations specifically are more likely to live below the poverty line, smoke cigarettes, report having poorer overall health and older African American adults are also more likely to live alone; all significant risk factors in cases of residential fire [11, 24, 36-38].

AT-RISK AREAS AND HOUSEHOLDS

Relative risk within houses

Research has shown there are a range of factors associated with the area of original of a residential fire that are significantly associated with the likelihood of residential fire fatalities, including;

- Room of fire origin,
- Cause of ignition,
- Awareness of the occupant/s at the time of ignition,
- Location of the occupant/s at the time of ignition, and
- Absence of a smoke alarm [4, 39, 40].

Residential fires are most likely to occur in areas of high daily occupancy such as the bedroom, lounge room or kitchen [10, 41]. However, fires that begin in the bedroom or lounge room are more likely to result in fatalities than those that occurred in the kitchen [4]. Fires that begin in the kitchen are also

less likely to require fire department intervention or spread beyond the room of fire origin [42]. This is likely to be related to the cause of ignition and awareness of the occupant/s at time of ignition.

Fires caused by inappropriately discarded smoking materials only account for 5% of residential fires, yet are the leading cause of fire-related death [1]. Fires caused by smoking materials and combustibles placed too close to a heat source are more likely to result in a fatality than cooking or electrical fires [4]. Cooking fires, however, are the most common cause of house fires and the leading cause of non-fatal fire-related injury [1]. It is likely that cooking fires may be less fatal because the occupants are likely to be awake, giving them more time to escape. In fact, occupants that are awake at the time of ignition and unimpaired by alcohol, drugs or disability are 12.9 times more likely to survive than those who are asleep [4].

The risk of casualty is significantly increased when the occupant is in the room of fire origin at the time of ignition [4]. Fires caused directly by human involvement are more likely to result in death than those that were not [4]. This is likely to be because fires spread out of control quickly and people are likely to be overcome within a short period of time, therefore making escape less likely when in close proximity to the fire [10]. Human activity during a fire can have a significant impact on ones risk of casualty. Most fatal fires occur at night during hours when people are likely to be asleep [41]. In fact, being asleep or having a physical disability are the most common factors contributing to death in house fires [41]. In addition to the above risk factors, certain areas are also at increased risk of fire-related casualty.

Area-level variation in risk of residential fire

It has been evident for some time that residential fire risk is not evenly distributed among society. Indeed, particular areas are at substantially higher risk than others. Research has found that rural areas, or areas with high proportions of older housing, vacant properties, unemployment/low income and Indigenous populations are more likely to experience residential fire [1, 43, 44]. In addition to at-risk areas, households that are rented, overcrowded, have children under 15 years, non-English speaking residents, or people who regularly smoke cigarettes/drink alcohol are also at increased risk [26, 44-46].

Rural areas are at increased risk for residential fire casualty. The smallest communities in the U.S. have the largest overall fire rates and fire-related fatality per capita [47]. The number of fires per 1,000 population and the frequency of fire incidents is higher in communities with a population of less than 5,000 [3]. Indeed, the rate of fire-related death in these communities is significantly higher than in communities with larger populations [3]. Rural areas are likely to be at increased risk for a number of reasons. First, these regions are more likely to have volunteer fire fighters, influencing factors such as response times and size of potential suppression forces [48]. Research comparing the differences in fire safety between rural and suburban communities has also found that rural residents are more likely to be on a low income and be over the age of 65; both risk factors for house fire casualty [49]. Finally, rural households are also less likely to own a smoke alarm or a telephone (to alert the fire department, should a fire occur) and twice as likely as suburban homes to use a space/gas heater as opposed to central heating.

With respect to disadvantage and low-SES areas, research has consistently found an increased occurrence of residential fire in areas with high proportions of low income/poverty. Indeed, Wuschke, Clare and Garis [50] found residential fire significantly clustered in areas with high levels of social disadvantage. Furthermore, Ducic and Ghezzo [45] found that house fires were more likely to occur in low income census tracks that had higher proportions of older housing. High income households are more likely to invest in fire safety equipment [51]. Furthermore, for low income households the purchase, use and maintenance of fire safety equipment may be postponed while income is limited [47]. In fact, individuals who live below the poverty line are less likely to have housing and appliances that meet fire safety standards and working smoke alarm/s within their homes [11, 12, 26]. One determinant of neighborhood decline and increased fire risk is the proportion of vacant properties within an area [46].

There is also an elevated risk of residential fire as a consequence of building occupancy, with house fires that occur in vacant properties account for 7% of residential fires overall in the U.S. [52]. On average, 25,000 vacant property fires occurred annually from 2010-2012, resulting in 60 deaths and 225 injuries per year. While the fire-related casualty rate among these properties is lower than occupied houses, these fires result in substantially more property damage, with the fire sometimes extending to surrounding properties. Vacant property fires also pose considerable risk to firefighters and nearby residents. Indeed, as mentioned by the U.S. Fire Administration [52], without knowing the state of the building, or whether or not there are people inside, entering a vacant property that is on fire can be particularly dangerous for firefighters. Furthermore, Schachterle et al. [48] found that the risk of fire in an area increases with each vacant property and the risk is heightened for households within 10 metres. From 2010-2012, in the U.S. approximately 11% of vacant house fires spread to nearby properties and while 89% stayed confined to the vacant household, 53% involved the entire house, compared to 14% of occupied house fires [52]. As well as at-risk areas and households, certain individuals are at significantly higher risk of dying/being injured in house fires than others.

LIFE SAFETY SYSTEMS

Internationally, smoke alarm use has increased substantially since the late 1970's – early 1980's [53]. Since smoke alarms have become widely available, many countries have made it mandatory by law to install smoke alarms in newly constructed households [54-56]. Today, research on the ownership and maintenance of smoke alarms is somewhat inconsistent. In the U.S., national research indicates that approximately 96% of households report having at least one smoke alarm [53]. As mentioned by Ahrens [57], this means that almost 5 million households in the U.S. remain unprotected by smoke detectors. However, research done at a county level found only 60.6% had at least one smoke alarm [49]. When considering the presence of smoke alarms in cases of residential fire, the research shows a substantial amount of fire-related deaths are occurring in houses with no functional smoke alarm present [57]. In fact, Garis and Clare [42] found that 74.3% of the house fires in their study had no present, functional smoke alarm. Indeed, whilst many households report owning a smoke alarm, the amount that own smoke alarms that actually work is much smaller. For example, Ahrens [58] found that 41% of residential fires in the U.S. occurred in houses with either no smoke alarm or no *functional* smoke alarms, 40% of deaths occurred in houses with no smoke alarm, whilst 23% of

fatalities had a smoke alarm, but it was not working. Similarly, Zhang et al. [27] found that 83.6% of older adults in their study owned a smoke alarm, yet only 72% had working smoke alarms. Disconnected/dead batteries was the most commonly cited reason for inoperative smoke alarms [57]. Ahrens [57] found that smoke alarms were most likely to be disabled due to nuisance alarms which are usually triggered due to cooking or smoking cigarettes.

Many households also do not have adequate smoke alarm protection [59]. According to Ahrens [57], 12% of the fires in their study did not trigger the smoke alarm as the fire was too small. Similarly, 1% of U.S. house fire deaths occur in houses with working smoke alarms that were not triggered by the fire. Smoke alarms need to be placed/maintained as per recommendations (such as the National Fire Protection Association recommendations) in order to ensure the entire house is fully protected [59]. When correctly placed and functioning at the time of fire, smoke alarms can provide enough warning for the occupants to escape and contact fire services, limiting the spread of the fire and resulting in significantly less damage [40]. In cases, where working smoke alarms were present but people still died, the victims were most likely;

- In the room of origin,
- Involved in ignition,
- Asleep,
- Unable to act (due to disability or time),
- Over the age of 65,
- Overcome by the fire (clothing ignited), or
- Under the influence of alcohol [1, 8, 29].

Other life safety systems, such as wet pipe sprinklers, while not as common, are even more effective at reducing fire-related casualty (both death and injury) and property damage [42].

FIRE RISK WITH AND WITHOUT PROTECTION OF LIFE SAFETY SYSTEMS

House fires with present, functioning smoke alarms are less likely to result in death and require fire department intervention than house fires without functional smoke alarms [42]. Indeed, houses with at least one functional smoke alarm are 49% less likely to result in fatality in the event of a fire [58]. While house fires that had a present, functional smoke alarm resulted in less fatality, they had higher overall injury rates than houses without smoke alarms [42]. This is likely to be because the smoke alarm alerted the resident to the fire and they began to engage in firefighting behavior when they experienced the fire-related injury.

Sprinkler protection, while more effective at reducing casualty, is less common [42]. In fact, Garis and Clare [42] found that only 1.6% of the house fires in their study had complete sprinkler protection. Residential fires that had sprinkler protection resulted in considerably lower fire-related casualty than residential fires overall. These households were also less likely to require fire department intervention and the fire was more likely to be contained to the room of fire origin.

Owning functional fire safety equipment can significantly reduce the risk of fire-related casualty [57]. However, the use/maintenance of fire safety equipment (such as smoke alarms), like fire itself, is also not uniformly distributed across society.

At-risk households and smoke alarm ownership/use

Households with children are more likely to have working smoke alarms installed [26]. However, the protective factors associated with smoke alarms are also lessened among this demographic. Children have higher auditory thresholds than adults when asleep and research has found that many children are likely to sleep through a standard residential smoke alarm [15-17]. Furthermore, children are also more likely to spend longer periods in stage 4 sleep than adults, putting them at further risk of sleeping through the alarm [15]. Only 12% of the children in Bruck and Thomas' [16, 17] studies were awoken by a smoke alarm in their house and of these, 49% did not know that the sound that woke them was in fact, a smoke alarm. Compared to all other fire causes, smoke alarms had no protective effect for intentionally set fires and fires caused by fire-play [30]. As children are involved in the ignition in cases of fire-play and are most likely to be injured/die from burns, it would suggest that the victims may be overcome by the fire before the smoke alarm is triggered or a guardian is able to intervene.

Analytical strategy and expectations

Based on this prior research and maintaining a focus on at risk populations in Canada, the current research uses the NFID information to examine residential fire outcomes. Particular attention is paid to demographic characteristics of residential fire fatalities and the presence of functioning life safety systems.

Residential fires as a sub-set of all reported incidents

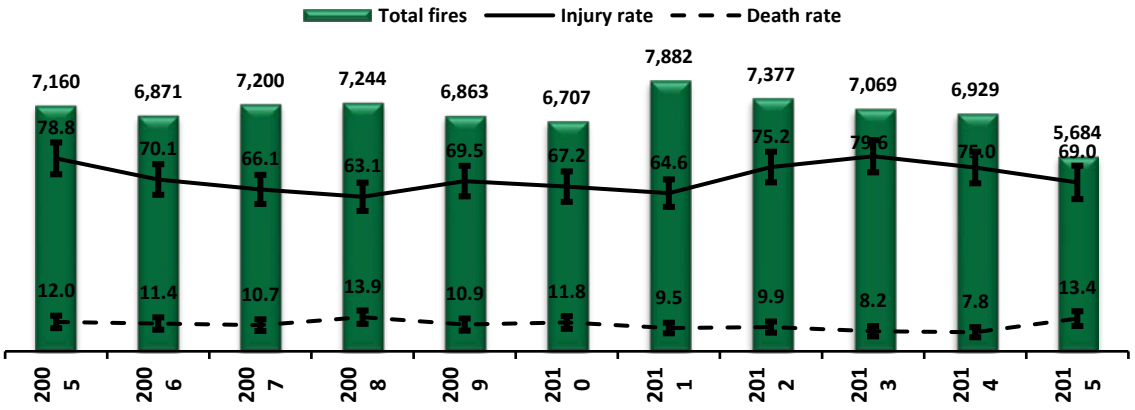
The complete NFID contains 467,929 fire incidents that resulted in 1,927 deaths and 13,399 injuries. Over 300,000 of these incidents (64.3%) were coded as having occurred in an 'unknown' or 'undetermined' occupancy group. For the remainder of fires (167,087, resulting in 1,038 deaths and 8,743 injuries)) fires that occurred in buildings identified as having a residential use accounted for 52.3% of fires and resulted in 82.4% of deaths and 64.9% of injuries. Given the focus of this research is on at risk populations, the remainder of this analysis will focus on this subset of the overall NFID. These fires were reported by Alberta, British Columbia, Manitoba, Ontario, and Saskatchewan.

Annual trends for residential fires and fire-related casualties

Figure 1 shows the annual trends for residential fires and fire-related casualties across the 11 years of data included in the NFID. With the exception of 2015, the number of reported residential fires each year was relatively stable (avg. 7,130 per year). The total number of residential fires in 2015 was 20.6% lower than the number reported in 2005. The rates of injuries (solid black line) and deaths (broken black line) per 1,000 fires each year are also displayed in Figure 1, along with 95%

confidence interval error bars for each annual rate estimate. These trends indicate there is year-to-year variation in the rate of these casualties, but the overall trends are relatively stable, with an average of 70.8 injuries and 10.9 deaths per 1,000 fires.

FIGURE 1. ANNUAL RESIDENTIAL FIRE COUNTS WITH INJURY AND FIRE RATES PER 1,000 FIRES (PLUS 95% CONFIDENCE INTERVALS)



Demographic details of residential fire casualties

Table 1 provides some age and sex information about the fire related casualties from the 11-years' of residential fires included in the NFID. Consistent with prior research, males were more likely to have been injured and killed in residential fires, relative to females. Also as expected, older adults were more likely to have been killed as a result of residential fires

TABLE 1. NON-FIREFIGHTER CASUALTY DEMOGRAPHIC INFORMATION (COUNTS AND RATES PER 100,000 PEOPLE) AND RELATIVE RISK OF CASUALTY FROM RESIDENTIAL FIRES

Demographic category	Deaths	Injuries	Death rate per 100,000 people	Injury rate per 100,000 people	Relative risk death (compared to whole population)	Relative risk injury (compared to whole population)
Male	549	2,815	4.6	23.4	1.3	1.2
Female	281	1,793	2.3	14.4	0.7	0.8
12 and under	79	994	2.2	27.7	0.7	1.5
13 to 18 years	24	173	1.5	10.5	0.4	0.6
19 to 64 years	482	2,086	3.2	13.7	0.9	0.7
65 to 79 years	160	250	5.5	8.5	1.6	0.4
80 years and over	84	96	8.1	9.3	2.4	0.5
Age unknown	1	1,057	NA	NA	NA	NA
Total	**830**	**4,656**	**3.4**	**19.0**		

NB. Population rates were based on 2016 Census age/sex population estimates published at http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/dt-td/Index-eng.cfm and residential fires were filtered to exclude incidents where the sprinkler presence was classified as 'blank' and 'not applicable – e.g., vehicle, outdoor, person'. This filter applies throughout the report.

Given the focus on at risk populations, all casualties involving firefighters have been excluded from the majority of this analysis. There were two fatalities of firefighters resulting from residential fires included in this sample. In comparison, there were 790 injuries sustained by firefighters, the severity of which are displayed in Table 2, relative to the severity of injuries sustained by non-firefighters. With respect to injuries, it is clear that overall, the majority of all injuries captured by the NFID were minor or light (85.4% of firefighter injuries vs. 78.5% for non-firefighters).

TABLE 2. RELATIVE SEVERITY OF INJURIES SUSTAINED BY FIREFIGHTERS AND NON-FIREFIGHTERS AS A CONSEQUENCE OF RESIDENTIAL FIRES

Injury severity	Firefighters		Non-firefighters	
	# injuries	% injuries	# injuries	% injuries
Minor injury (less than one day hospital or off work)	546	69.1%	2,622	56.3%
Light injury (hospitalised 1-2 days and/or off work 1-15 days)	129	16.3%	1,034	22.2%
Serious injury (hospitalised 3+ days and/or off work 16+ days)	89	11.3%	815	17.5%
Injury - seriousness unknown	0	0.0%	25	0.5%
Unknown/Undetermined/Other	26	3.3%	160	3.4%
Total	**790**	**100.0%**	**4,656**	**100.0%**

Behaviors of residential fire casualties

This section examines what is known about the behavior of the non-firefighter residential fire casualties. Table 3 shows the condition of each casualty and it is clear that there is a large amount of uncertainty relating to this variable: 44.2% of deaths and 25.7% of injuries were 'unclassified' or 'unknown'. Analysis of corrected percentages that excluded these uncertain cases revealed that 32.6% of fatalities were asleep at the time of fire, 30.9% were impaired by alcohol, drugs, or medication, and 21.4% were awake with no physical/mental impairments. For injuries, almost two-thirds (61.1%) of cases involved a casualty who was awake with no physical/mental impairments at the time of the fire and one-quarter (24.2%) were asleep at the time of the fire.

TABLE 3. CONDITION OF CASAULTY FOR NON-FIREFIGHER CASUALTIES FROM RESIDENTIAL FIRES

Non-firefighter condition of casualty	# Deaths	% Deaths	# Injuries	% Injuries
Hearing impaired	2	0.2%	0	0.0%
Visually impaired	1	0.1%	0	0.0%
Asleep at time of fire	151	18.2%	838	18.0%
Bedridden or other physical handicap	42	5.1%	81	1.7%
Impairment by alcohol, drugs or medication	143	17.2%	320	6.9%
Awake and no physical or mental impairment at the time of fire	99	11.9%	2,113	45.4%
Under restraint or detention	1	0.1%	3	0.1%
Too young to react to fire emergency	8	1.0%	57	1.2%
Mental handicap - includes senility	11	1.3%	22	0.5%
Child left unattended	5	0.6%	24	0.5%
Condition of casualty - unclassified	48	5.8%	240	5.2%
Condition of casualty - unknown	319	38.4%	958	20.6%
Total	**830**	**100.0%**	**4,656**	**79.4%**

Once again, when examining the cause of failure to escape for non-firefighter casualties, a lot of incidents were classified as 'unknown' (Table 4): with two-thirds (62.5%) of deaths and over 90% of injuries coded this way. Analysis of corrected percentages that excluded these uncertain cases revealed that 51.1% of deaths resulted from rapidly spreading fire/smoke, 14.5% resulted from high flame spread of combustible interior finish, and only 7.4% of the known reasons for failure to escape were as a result of age and/or other physical limitations. Being trapped by fire/smoke was also a major cause of failure to escape resulting in non-firefighter injuries (49.4% of known injuries) and explosion accounted for 20.3% of known injuries. In comparison, 41.3% of the 727 firefighter injuries resulted from falling debris, 22.2% from rapid spreading fire/smoke, and 12.7% from building collapse (NB: values for firefighter injuries are not shown in Table 4).

TABLE 4. CAUSE OF FAILURE TO ESCAPE FOR NON-FIREFIGHER CASUALTIES FROM RESIDENTIAL FIRES

Cause of failure to escape	# Deaths	% Deaths	# Injuries	% Injuries
Trapped by rapid spreading of fire/smoke - vertical openings, stairways, elevators	53	6.4%	112	2.4%
Trapped by rapid spreading of fire/smoke - through horizontal openings	106	12.8%	110	2.4%
High flame spread of combustible interior finish	45	5.4%	68	1.5%
Building collapse	1	0.1%	2	0.0%
Falling debris	2	0.2%	3	0.1%
Explosion	17	2.0%	91	2.0%
Exit blocked, locked, or obstructed	19	2.3%	35	0.8%
Outdoor fire - includes forest/brush fires	1	0.1%	14	0.3%
Fell, slipped or tripped	0	0.0%	1	0.0%
Exposure to fire products	8	1.0%	10	0.2%
Trapped (or caught) - type of openings unknown	31	3.7%	2	0.0%
Exposure to hazardous materials of toxic fumes	0	0.0%	0	0.0%
Exposure to hazard, type unknown	0	0.0%	0	0.0%
Age and/or other physical imitation	23	2.8%	0	0.0%
Multiple Causes	0	0.0%	1	0.0%
Not applicable - escaped	1	0.1%	0	0.0%
Not applicable - suicide	4	0.5%	0	0.0%
Unknown	519	62.5%	4,207	90.4%
Total	**830**	**100.0%**	**4,656**	**100.0%**

The final avenue of insight into the behaviors of the non-firefighter residential fire casualties was the classification of the action taken by each casualty (Table 5). Once again, there were a large number of 'unknown' incidents with respect to this variable: 58.3% of deaths and 24.5% of injuries. With these records removed, the corrected percentages indicated that one-third (36.4%) of fatalities were attempting to escape, one-quarter (28.6%) did not act, and 14.2% experienced a loss of judgement or panic. When the action of the casualty was known for injuries, 50.4% of cases involved the person entering/remaining for rescue, fire fighting, or saving personal property. The remainder of cases involved injuries sustained when trying to escape (26.8%), a loss of judgement (11.4%), or a failure to act (6.9%). In comparison, 94.8% of the 727 firefighter injuries were sustained while entering/remaining for rescue (7.9%), fire fighting (86.3%), or saving personal property (0.6%, with values for firefighter injuries not shown in Table 5).

TABLE 5. ACTION OF CASAULTY FOR NON-FIREFIGHER CASUALTIES FROM RESIDENTIAL FIRES

Action of casualty	# Deaths	% Deaths	# Injuries	% Injuries
Civilian attempted suppression	5	0.6%	0	0.0%
Fire setter	4	0.5%	0	0.0%
Injured while attempting to escape	126	15.2%	941	20.2%
Over-exertion, heart attack	5	0.6%	15	0.3%
Entered or remained for rescue purposes	17	2.0%	215	4.6%
Entered or remained for firefighting/extinguishment	12	1.4%	1375	29.5%
Entered or remained to save personal property	8	1.0%	180	3.9%
Loss of judgement or panic	49	5.9%	401	8.6%
Received delayed warning	21	2.5%	66	1.4%
Did not act	99	11.9%	322	6.9%
Unknown	484	58.3%	1141	24.5%
Total	**830**	**100.0%**	**4,656**	**100.0%**

Residential fires that result in casualties

To understand more about the residential fires that did result in casualties, this section examines how fire casualties were influenced by (a) the extent of fire spread (Table 6), and (b) the method of fire control (Table 7). Consistent with previous research, Table 6 indicates that the death rate from residential fire increased along with the extent of fire spread. Fires that were contained to the room of origin (43.6%) resulted in 56.9% of injuries and 23.6% of deaths, at a rate of 79.2 injuries and 3.8 deaths per 1,000 fires. In comparison, fires that extended beyond the room and as far as beyond the property of origin (22.3%) resulted in 27.9% of injuries and 58.7% of deaths (75.9 injuries and 28.4 deaths per 1,000 fires, respectively).

TABLE 6. EXTENT OF FIRE SPREAD AND CASUALTIES CAUSED BY RESIDENTIAL FIRES

Extent of fire spread	Total Fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
Confined to object of origin	15,203	19.8%	687	14.8%	39	4.7%	45.2	2.6
Confined to part of room/area of origin	13,687	17.9%	1,359	29.2%	87	10.5%	99.3	6.4
Confined to room of origin	4,564	6.0%	603	13.0%	70	8.4%	132.1	15.3
Confined to floor level of origin	3,052	4.0%	445	9.6%	103	12.4%	145.8	33.7
Confined to building of origin	10,719	14.0%	690	14.8%	339	40.8%	64.4	31.6
Extended beyond property of origin	3,359	4.4%	165	3.5%	45	5.4%	49.1	13.4
Confined to roof/attic space	780	1.0%	5	0.1%	0	0.0%	6.4	0.0
Other*	25,311	33.0%	702	15.1%	147	17.7%	27.7	5.8
Total	**76,675**	**67.0%**	**4,656**	**100.0%**	**830**	**100.0%**	**60.7**	**10.8**

NB. 'Other' here combines 'not applicable', 'unclassified', 'unknown', and 'not available'.

Also consistent with previous research, Table 7 demonstrates the relationship between method of fire control and fire casualties. Fires that required fire department intervention (36.8%) resulted in 33.7% of injuries and 62.8% of deaths (at a rate of 18.5 deaths per 1,000 fires). In comparison, when

fires were extinguished using hand held extinguishers or makeshift fire fighting aids (17.0% of fires) there was a death rate of 1.7 per 1,000 fires.

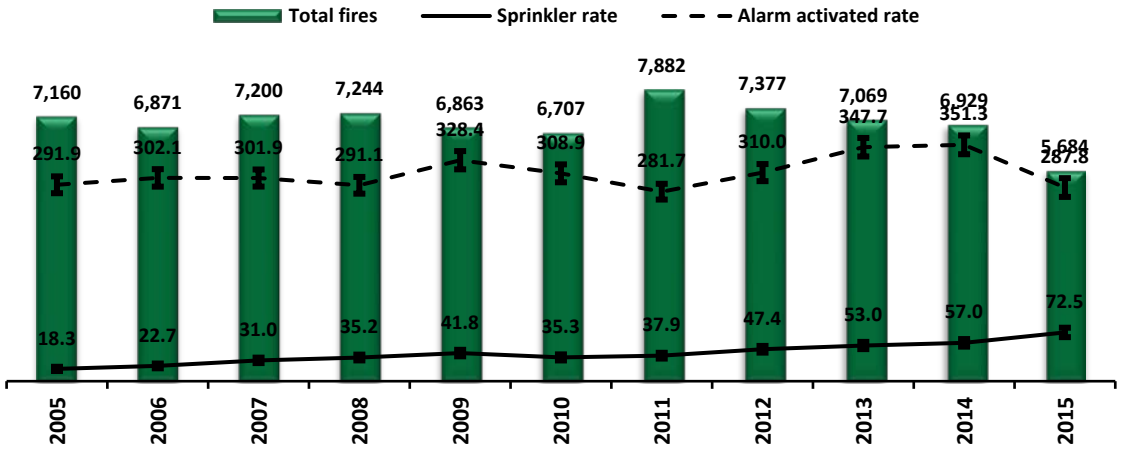
TABLE 7. METHOD OF FIRE CONTROL AND CASUALTIES CAUSED BY RESIDENTIAL FIRES

Method of fire control	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
Hand held extinguisher	5,763	7.5%	336	7.2%	8	1.0%	58.3	1.4
Standpipe and hose systems	756	1.0%	46	1.0%	12	1.4%	60.8	15.9
Makeshift firefighting aids	7,264	9.5%	497	10.7%	14	1.7%	68.4	1.9
Fire Department - water application	26,490	34.5%	1,524	32.7%	503	60.6%	57.5	19.0
Fire Department - other than water	1,742	2.3%	45	1.0%	18	2.2%	25.8	10.3
Sprinkler protection	833	1.1%	61	1.3%	3	0.4%	73.2	3.6
Fixed system other than sprinklers	111	0.1%	9	0.2%	0	0.0%	81.1	0.0
Burned out	6,285	8.2%	226	4.9%	37	4.5%	36.0	5.9
Miscellaneous method of fire control/extinguishment	3,610	4.7%	123	2.6%	3	0.4%	34.1	0.8
10. Cannot be determined	23,821	31.1%	1,789	38.4%	232	28.0%	75.1	9.7
Total	**76,675**	**100.0%**	**4,656**	**100.0%**	**830**	**100.0%**	**60.7**	**10.8**

Cumulative protective influence of life safety systems

This section examines the cumulative influence of life safety systems on reducing the likelihood of death as a result of residential fire. Figure 2 shows the annual trends with respect to complete residential sprinkler protection (solid black line) and smoke alarm activation (broken black line) as rates per 1,000 fires each year (with 95% confidence interval error bars). With some fluctuation from year-to-year, the average rate of activation of working smoke alarms was 309.4 per 1,000 fires (with 2015 figures below this). In comparison, there has been a steady year-on-year increase in the presence of sprinkler protection in residential buildings, increasing to 72.5 per 1,000 fires in 2015.

FIGURE 2. ANNUAL RESIDENTIAL FIRE COUNTS WITH FIRE SAFETY SYSTEM PRESENCE AS A RATE PER 1,000 FIRES (PLUS 95% CONFIDENCE INTERVALS)



Comparisons between the provinces that submitted data for analysis in the NFID indicates there was a wide range of fire safety coverage across areas in Canada (averaged over the full time period, Table 8).

TABLE 8. RELATIVE COVERAGE OF COMPLETE SPRINKLER PROTECTION AND ACTIVATED SMOKE ALARMS BY PROVINCE

Province	# fires	% sprinkler	% smoke alarm
Alberta	18,939	3.3%	17.0%
British Columbia	24,375	8.8%	33.9%
Manitoba	13,710	2.5%	29.0%
Ontario	18,070	0.0%	45.6%
Saskatchewan	1,581	0.0%	7.1%
Total	**76,675**	**4.1%**	**31.1%**

With respect to fire safety systems and the presence of sprinklers, Table 9 shows patterns consistent with prior research. Relatively few fires (4.1%) had complete sprinkler protection and two-thirds of fires had no sprinklers. Comparing between these two groups, death and injury rates were much lower in the presence of complete sprinkler protection (1.3 deaths per 1,000 fires, compared to 11.3 deaths per 1,000 fires with no sprinkler protection).

TABLE 9. SPRINKLER PROTECTION AND CASUALTIES CAUSED BY RESIDENTIAL FIRES

Sprinkler protection	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
Complete sprinkler protection	3,120	4.1%	181	3.9%	4	0.5%	58.0	1.3
Partial sprinkler protection	1,054	1.4%	75	1.6%	10	1.2%	71.2	9.5
No sprinkler protection	51,106	66.7%	3,220	69.2%	575	69.3%	63.0	11.3
Sprinkler protection unclassified	2,957	3.9%	287	6.2%	1	0.1%	97.1	0.3
Cannot be determined	18,438	24.0%	893	19.2%	240	28.9%	48.4	13.0
Total	**76,675**	**100.0%**	**4,656**	**100.0%**	**830**	**100.0%**	**60.7**	**10.8**

Table 10 shows the impact of smoke alarms on casualty outcomes. As expected, the relative death rates per 1,000 fires was significantly lower for the 31.1% of fires when the smoke alarm was activated (6.8 per 1,000 fires), compared to fires where the alarm was not activated or was not installed (14.1 and 10.2 per 1,000 fires, respectively). As with previous research, the injury rate was highest in the presence of a working smoke alarm: consistent with casualties fighting fires.

TABLE 10. SMOKE ALARM PROTECTION AND CASUALTIES CAUSED BY RESIDENTIAL FIRES

Smoke alarm status	Total fires	% fires	Injuries	% injuries	Deaths	% deaths	Injury rate	Death rate
Alarm activated	23,810	31.1%	2,114	45.4%	163	19.6%	88.8	6.8
Alarm not activated	6,292	8.2%	512	11.0%	89	10.7%	81.4	14.1
Not enough smoke to activate smoke alarm	1,400	1.8%	57	1.2%	8	1.0%	40.7	5.7
No smoke alarm installed	19,456	25.4%	706	15.2%	199	24.0%	36.3	10.2
Cannot be determine/not applicable*	25,717	33.5%	1,267	27.2%	371	44.7%	49.3	14.4
Total	**76,675**	**100.0%**	**4,656**	**100.0%**	**830**	**100.0%**	**60.7**	**10.8**

* Combined 'not applicable', 'unknown', and 'not available'.

Table 11 summarizes the findings from this section. This table presents the relative trends as a function of the combination of life safety systems that were in place for each residential fire. Table 11 also provides 95% confidence intervals for the estimates of death rates, fire department intervention, and the extent of fire spread for each of these combinations of life safety systems. The main findings from Table 11 include:

- Just over two-thirds of these residential fires had no present, functioning life-safety systems and these fires resulted in 80.4% of the deaths in this sample.
- Relative to fires with no life safety systems in place, fires with either a working smoke alarm or complete sprinkler protection are much less likely to result in a death, less likely to require fire department intervention, and less likely to extend beyond the room of origin.
- The compound effect of both sprinkler protection and a working smoke alarm resulted in only 4 deaths, required the least amount of fire department intervention, and the fires did not extend beyond the room of origin 94% of the time.

TABLE 11. RESIDENTIAL FIRES, FIRE-RELATED CASUALTIES, FIRE DEPARTMENT INVOLVEMENT, AND EXTENT OF FIRE SPREAD BY COMBINATIONS OF LIFE SAFETY SYSTEMS

Smoke alarm	Sprinkler	Fires (% total)	Injuries (% total)	Injury rate (95% CI)	Deaths (% total)	Death rate (95% CI)	% Fire department extinguish (95% CI)	% Beyond room of origin (95% CI)
Yes	Yes	1,808 (2.4%)	108 (2.3%)	59.7 (48.5, 71.0)	4 (0.5%)	2.2 (0.0, 4.4)	15.8% (13.9%, 17.6%)	5.8% (4.6%, 7.0%)
No	Yes	1,312 (1.7%)	73 (1.6%)	55.6 (42.9, 68.4)	0 (0.0%)	0.0 (0.0, 0.0)	28.3% (25.3%, 31.2%)	16.5% (14.2%, 18.8%)
Yes	No	22,002 (28.7%)	2,006 (43.1%)	91.2 (87.2, 95.2)	159 (19.2%)	7.2 (6.1, 8.3)	39.6% (38.6%, 40.7%)	18.0% (17.3%, 18.7%)
No	No	51,864 (67.6%)	2,469 (53.0%)	48.1 (45.7, 49.5)	667 (80.4%)	12.9 (11.9, 13.8)	43.1% (42.6%, 43.7%)	42.9% (42.2%, 43.6%)
Total		***76,675*** ***(100.0%)***	***4,656*** ***(100.0%)***	***60.7*** ***(59.0, 62.5)***	***830*** ***(100.00%)***	***10.8*** ***(10.1, 11.6)***	***41.5%*** ***(41.0%, 41.9%)***	***33.9%*** ***(33.4%, 34.4%)***

Policy implications of these findings

In aggregate, and in light of previous similar research, there are no real surprising findings from this analysis of fire related casualties from the NFID. Overall, there is an elevated risk for males and older residents, and there are protective benefits of life safety systems when they are in-place. There is also a notable absence of fire safety systems in a large proportion of the properties that experienced residential fires. According to the U.N. [52], almost every country in the world is experiencing an ageing population, with figures estimating the number of adults aged 60+ years worldwide will grow by 56% from 2015-2030. Considering this, if preventative measures are not put in place it is likely the amount of fire-related casualties among this demographic will only increase with time.

With these trends in mind, the researchers would encourage the relevant Canadian agencies to commence targeted problem-prevention strategies to increase coverage of working smoke alarms for vulnerable residents. These interventions could build on frameworks that have been demonstrated as effective in reducing other non-random social problems (such as disease and crime). The key components to these strategies usually involve clear definition of the problem (i.e., what needs to change), analysis of available data to give insight into the non-random nature of the

problem, inter-agency collaboration to implementation interventions designed to reduce the problem, and solid evaluation to ensure the interventions have been implemented and are effective. Without being clear about what your problems are, it is not possible to design and implement effective, targeted interventions that have the greatest likelihood of success. The findings outlined here (in combination with the summary from the available literature in this area) provide an excellent platform for locally-specific, data-driven, targeted interventions to reduce risk for the most vulnerable populations in Canada. Furthermore, given the large number of 'unknown' responses captured in the NFID, to date, the researchers would also implore the relevant agencies to do all they can to improve data collection (training and recording) to reduce this issue into the future.

In conclusions, we urge the Canadian fire service to adopt a proactive, partnership-based, prevention focus to maximise the potential for elderly residents to remain living safely in their own homes for longer. In addition to targeting preventable fires, this initiative could also attempt to reduce the risks of trips/falls and crime victimisation. Given the consistency of findings relating to the elevated risk for this sub-section of the population, it is unacceptable to fail to act.

References

1. Ahrens, M., *Characteristics of home fire victims.* National Fire Protection Association, 2014: p. 1-100.
2. Wijayasinghe, M., *Fire losses in Canada: 2007 and selected years.* 2011.
3. Haynes, H.J.G., *Fire loss in the United States during 2015.* National Fire Protection Association, 2016.
4. Xiong, L., D. Bruck, and M. Ball, *Comparative investigation of 'survival' and fatality factors in accidental residential fires.* Fire Safety Journal, 2015. **73**: p. 37-47.
5. Runyan, C.W., et al., *Risk Factors for Fatal Residential Fires.* The New England Journal of Medicine, 1992. **327**(12): p. 859-863.
6. United States Fire Administration, *Fire and the older adult*. 2006. p. 1-7.
7. Evarts, B., *Human factors contributing to fatal injury.* National Fire Protection Association, 2011.
8. Holborn, P.G., P.F. Nolan, and J. Golt, *An analysis of fatal unintentional dwelling fires investigated by London Fire Brigade between 1996 and 2000.* Fire Safety Journal, 2003. **38**(1): p. 1-42.
9. Kobes, M. and R. van den Dikkenberg, *An analysis of residential building fire rescues: The difference between fatal and non-fatal casualties*. 2016, Institute for Safety, Fire Service Academy.
10. Miller, I., *Human behaviour contributing to unintentional residential fire deaths 1997-2003.* New Zealand Fire Service Commission Research Report 2005. **47**.
11. United States Fire Administration, *Fire risk to older adults in 2010. Topical Fire Report Series, 14(9)*. 2013. p. 1-8.
12. United States Fire Administration, *Fire risk to children in 2010. Topical Fire Report Series, 14(8)*. 2013. p. 1-7.
13. Velluti, R.A., *Interactions between sleep and sensory physiology.* Journal of sleep research, 1997. **6**(2): p. 61-77.
14. United States Department of Health and Human Services, *Age-related hearing loss: National Institute on Deafness and Other Communication Disorders*. 2017.
15. Bruck, D. and M. Ball, *Optimizing Emergency Awakening to Audible Smoke Alarms: An Update.* Human Factors: The Journal of the Human Factors and Ergonomics Society, 2007. **49**(4): p. 585-601.
16. Bruck, D. and I. Thomas, *Optimising fire alarm notification for high risk groups research project: Waking effectiveness of alarms (auditory, tactile, visual) for adults who are hard of hearing.* The Fire Protection Research Association, 2007.
17. Bruck, D. and I. Thomas, *Strobe lights versus auditory smoke alarm signals: Effectiveness for waking up selected populations.* The Irish Journal of Psychology, 2009. **30**(1-2): p. 21-36.
18. Kemmet, D. and S. Brotherson, *Making sense of sensory losses as we age*, in *North Dakota State University*. 2015.

19. Carskadon, M.A. and R.S. Hers, *Minimal Olfactory Perception During Sleep: Why Odor Alarms Will Not Work for Humans.* Sleep, 2004. **27**(3).

20. Heiser, C., et al., *Effects of an Artificial Smoke on Arousals During Human Sleep.* Chemosensory Perception, 2012. **5**(3): p. 274-279.

21. He, W. and L.J. Larson, *Older Americans with a disability: 2008-2012.* American Community Survey Reports, 2014.

22. Marshall, S.W., et al., *Fatal Residential Fires: Who Dies and Who Survives?* JAMA, 1998. **279**(20): p. 1633-1637.

23. Coty, M.-B., et al., *Home fire safety beliefs and practices in homes of urban older adults.* Geriatric nursing (New York, N.Y.), 2015. **36**(3): p. 177-181.

24. Federal Interagency Forum on Ageing Related Statistics, *Older Americans: Key Indicators of Wellbeing*. 2016.

25. Rowland, D., et al., *Prevalence Of Working Smoke Alarms In Local Authority Inner City Housing: Randomised Controlled Trial.* BMJ: British Medical Journal, 2002. **325**(7371): p. 998-1001.

26. Ballesteros, M.F. and M.-j. Kresnow, *Prevalence of Residential Smoke Alarms and Fire Escape Plans in the U.S.: Results from the Second Injury Control and Risk Survey (ICARIS-2).* Public Health Reports (1974-), 2007. **122**(2): p. 224-231.

27. Zhang, G., et al., *Fire safety among the elderly in Western Australia.* Fire Safety Journal, 2006. **41**(1): p. 57-61.

28. Barillo, D.J. and R. Goode, *Fire fatality study: demographics of fire victims.* Burns : journal of the International Society for Burn Injuries, 1996. **22**(2): p. 85-88.

29. Harpur, A.P., K.E. Boyce, and N.C. McConnell, *An investigation into the circumstances surrounding fatal dwelling fires involving very young children.* Fire Safety Journal, 2013. **61**: p. 72-82.

30. Istre, G.R., et al., *Residential fire related deaths and injuries among children: fireplay, smoke alarms, and prevention.* Injury prevention : journal of the International Society for Child and Adolescent Injury Prevention, 2002. **8**(2): p. 128-132.

31. Kool, B., *Unintentional fire-related childhood injuries in Auckland resulting in hospitalisation or death 1989 - 1998.* New Zealand Fire Service Commission Research Report, 2001. **13**.

32. Mather, M., *Children in single-mother families*. 2010, Population Reference Bureau – Data Brief.

33. Pooley, K. and C.E. Ferguson, *Using environmental criminology theories to compare 'youth misuse of fire' across age groups in New South Wales.* Australian & New Zealand Journal of Criminology, 2015.

34. Gilbert, M., M. Dawar, and R. Armour, *Fire-related Deaths Among Aboriginal People in British Columbia, 1991-2001.* Canadian Journal of Public Health / Revue Canadienne de Sante'e Publique, 2006. **97**(4): p. 300-304.

35. United States Census Bureau, *Quick Facts – Population Estimates*. 2016.

36. Centre for Disease Control and Prevention, *Health of American Indian or Alaskan Native population*. 2015, National Centre for Health Statistics.

37. Centre for Disease Control and Prevention, *Health of white non-Hispanic population*. 2015, National Centre for Health Statistics.

38. McCartney, S., A. Bishaw, and K. Fontenot, *Poverty rates for selected detailed race and Hispanic groups by state and place: 2007-2011*. 2013, American Community Survey Briefs.

39. Hasofer, A.M. and I. Thomas, *Analysis of fatalities and injuries in building fire statistics.* Fire Safety Journal, 2006. **41**(1): p. 2-14.

40. Garis, L., J. Clare, and S. Hughan, *Smoke alarms work, but not forever: revisited - successes and ongoing challenges from BC's working smoke alarm campaign.* 2015.

41. United States Fire Administration, *Civilian fire fatalities in residential buildings (2012-2014). Topical Fire Report Series, 17(4)*. 2016. p. 1-10.

42. Garis, L. and J. Clare, *Life safety systems, fire department intervention and residential fire outcomes: Analysis of 28 years of BC fire incident reports: 1988-2015.* 2016.

43. Chhetri, P., et al., *Modelling potential socio-economic determinants of building fires in South East Queensland.* Geographical Research, 2010. **48**(1): p. 75.

44. Shai, D., *Income, housing, and fire injuries: A census tract analysis.* Public Health Reports (1974-), 2006. **121**(2): p. 149-154.

45. Ducic, S. and H.R. Ghesso, *Epidemiology of accidental home fires in Montreal.* Accident Analysis and Prevention, 1980. **12**(1): p. 67-73.

46. Jennings, C.R., *Socioeconomic characteristics and their relationship to fire incidence: A review of the literature.* Fire Technology, 1999. **35**(1): p. 7-34.

47. Diekman, S., M.F. Ballesteros, and M. Ahrens, *Home fires in America: Progress and opportunities.* American Journal of Lifestyle Medicine, 2012. **6**(2): p. 141-151.

48. Schachterle, S.E., et al., *Proximity to vacant buildings is associated with increased fire risk in Baltimore, Maryland, homes.* Journal of the International Society for Child and Adolescent Injury Prevention, 2012. **18**(2): p. 98-102.

49. Jones, A.R., C.J. Thompson, and M.K. Davis, *Smoke alarm ownership and installation: A comparison of a rural and a suburban community in Georgia.* Journal of Community Health, 2001. **26**(5): p. 307-329.

50. Wuschke, K., J. Clare, and L. Garis, *Temporal and geographic clustering of residential structure fires: A theoretical platform for targeted fire prevention.* Fire Safety Journal, 2013. **62**: p. 3-12.

51. Jennings, C.R., *Social and economic characteristics as determinants of residential fire risk in urban neighbourhoods: A review of the literature.* Fire Safety Journal, 2013. **62**(13-19).

52. United States Fire Administration, *Vacant residential building fires (2010-2012). Topical Fire Report Series, 15(11)*. 2015. p. 1-11.

53. Greene, M.A. and C. Andres, *2004-2005 National sample survey of unreported residential fires.* U.S. Consumer Product Safety Commission, 2009.

54. Department for Communities & Local Government, *The smoke and carbon monoxide alarm (England) regulations 2015*. 2015.

55. Department of Fire & Emergency Services, *Smoke alarm legislative requirements.* 2017.

56. McLoughlin, E., et al., *Smoke detector legislation: Its effect on owner-occupied homes.* American Journal of Public Health, 1985. **75**(8): p. 1-5.

57. Ahrens, M., *Smoke alarms in U.S. house fires.* National Fire Protection Association, 2015.

58. Ahrens, M., *Smoke Alarm Presence and Performance in U.S. Home Fires.* Fire Technology, 2011. **47**(3): p. 699-720.

59. Peek-Asa, C., et al., *When one is not enough: prevalence and characteristics of homes not adequately protected by smoke alarms.* Journal of the International Society for Child and Adolescent Injury Prevention, 2005. **11**(6): p. 364.

Author Biographical Information

Dr Joseph Clare, formerly of the Surrey Fire Service, is a Senior Lecturer in Criminology at Murdoch University, and an international member of the Institute of Canadian Urban Research Studies, Simon Fraser University. Contact him at j.clare@murdoch.edu.au

Ms Hannah Kelly is has a First Class Honours degree in Criminology and has worked with Dr Clare on a number of fire prevention projects.

UNIVERSITY OF THE FRASER VALLEY
CENTRE FOR PUBLIC SAFETY & CRIMINAL JUSTICE RESEARCH

Murdoch UNIVERSITY