



Comparison of causes, characteristics and consequences of residential fires in social and non-social housing dwellings in New South Wales, Australia

Nargess Ghassempour^{a,b,*}, W. Kathy Tannous^{a,c}, Kingsley E. Agho^{c,d}, Gulay Avsar^a, Lara A. Harvey^{e,f}

^a School of Business, Western Sydney University, Parramatta, NSW 2150, Australia

^b Rozetta Institute, The Rocks, NSW 2000, Australia

^c Translational Health Research Institute, Western Sydney University, Campbelltown, NSW 2560, Australia

^d School of Health Sciences, Western Sydney University, Penrith, NSW 2751, Australia

^e Fall, Balance and Injury Research Centre, Neuroscience Research Australia, Randwick, NSW 2031, Australia

^f School of Population Health, University of New South Wales, Kensington, NSW 2033, Australia

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ABSTRACT

There are over 17,000 residential fire incidents in Australia annually, of which 6,500 occur in New South Wales (NSW). The number of state-provided accommodations for those on low incomes (social housing), is over 437,000 in Australia of which 34% are located in NSW. This study compared causes, characteristics and consequences of residential fires in social and non-social housing in NSW, Australia.

This population-based study used linked fire brigade and health service data to identify those who experienced a residential fire incident from 2005 to 2014. Over the study period, 43,707 residential fires were reported, of which 5,073 (11.6%) occurred in social housing properties.

Fires in social housing were more likely to occur in apartments (RR 1.85, 95%CI 1.75–1.96), caused by matches and lighters (RR 1.62, 95%CI 1.51–1.74) and smokers' materials (RR 1.51, 95%CI 1.34 – 1.71). The risk of health service utilisation or hospital admission was 16% (RR 1.16, 95%CI 1.04–1.28) and 25% (RR 1.25, 95%CI 1.02–1.51) higher in social housing respectively. Those aged 25–65 were at 40% (RR 1.40, 95%CI 1.14 – 1.73) higher risk of using residential fire-related health services. Almost 88% of social housing properties did not have a functioning fire detector of any type, and 1.2% were equipped with sprinklers.

Overall, the risk of residential fire incidents and associated injuries was higher for residents in social housing. Risk mitigation strategies beyond the current provision of smoke alarms are required to reduce the impact of residential fires in social and non-social housing.

1. Background

Globally fires are devastating events and cause an estimated 265,000 deaths each year (World Health Organization, 2014). Fire-related burns are ranked as the fourth most common cause of unintentional trauma, and burns remain the third leading cause of unintentional injury in the home (World Health Organization, 2014). In most industrialised countries, including Australia, a high proportion of fire-related deaths and injuries are related to residential fires (Division, 2008; Division, 2009). In 2020, there were 17,915 residential fire incidents in Australia, of which 6591 occurred in New South Wales (NSW) (Australia Productivity Commission, 2020; Australian Bureau of Statistics, 2019; Australia

Productivity Commission, 2021).

Existing literature has extensively discussed factors associated with residential fires and individuals characteristics, their socio-economic conditions, the built environment that they are living in and the fire circumstances. Individual characteristics such as age, gender, socio-economic status, occupants behaviour, poor mobility or alcohol intoxication (Xiong et al., 2017; Xiong et al., 2015; Tannous and Agho, 2017; Jonsson, 2017; Jonsson et al., 2017; Jonsson and Jaldell, 2020; Nilson and Bonander, 2021; Turner et al., 2017; Harpur et al., 2013; Runefors and Nilson, 2021) as well as the type of building (Xiong et al., 2015; Špatenková and Virrantaus, 2013), furniture (Thomas et al., 2016), smoke alarm and fire safety measures (Thomas and Bruck, 2010; Istre

* Corresponding author at: School of Business, Western Sydney University, Parramatta, NSW 2150, Australia.

E-mail address: N.Ghassempour@westernsydney.edu.au (N. Ghassempour).

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et al., 2001) and fire circumstances such as electricity, cooking and smoking materials (Xiong et al., 2015; Ahrens, 2013; Xiong et al., 2017) have been associated as risk and protective factors for deaths and injuries in residential fire incidents. Those younger than 5 years old or older than 65, being male, being unemployed and having lower educational attainment, alcohol and smoking and living in socioeconomically disadvantaged areas have been shown to increase the risk of experiencing residential fires and worsen health outcomes.

Residential fire incidents are also linked to building characteristics and dwelling types. The dilapidated state of the buildings, as well as higher proportion of flats and apartments, mobile homes, historic buildings and multi-storey buildings are more likely to experience fire compared to detached and semi-detached buildings (Turner et al., 2017). Upholstered furniture, mattresses and bedding have been shown to increase the risk of residential fires (Thomas et al., 2016). 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 (Xiong et al., 2017). Furthermore, presence of active smoke alarms and other fire safety measures such as sprinkler systems (Garis et al., 2017; Downey, 2010) and having a home-fire escape plan or changes in children nightwear (Harvey et al., 2015) have been identified as residential fire-related death and injuries protective factors. Contradictory results for other safety measures have also been shown, such as introducing fire safe cigarettes (Bonander et al., 2018) and campaigns (Lu et al., 2016) and changes to upholstery (Shaw, 2010).

Smoke alarms have been mandated for all houses in NSW since May 2006 as fire risk mitigation appliances to warn occupants of a fire incident. Under the legislation, every home must have at least one operational smoke alarm, and it should be placed between the living and sleeping areas. In the case of multi-level dwellings, at least one smoke alarm is required for each level. Prior to 2006, smoke alarms were only mandatory in new buildings and existing buildings undergoing substantial renovations (Harvey et al., 2013; Wales et al., 2006). It has been shown that working smoke alarms reduce about half of the cases of residential fire fatalities (Ahrens, 2008).

There are some limiting factors for smoke alarms, however, such as the possibility for poor functionality due to a dead battery, an inadequate power source or incorrect placement in the home, and their failure to alert sleeping residents or those with hearing impairment (Garis and Clare, 2013). In addition, residential occupants alerted by a smoke alarm may not have the physical or cognitive capacity to evacuate safely. Previous literature has indicated that for a specific socio-economic subgroup of individuals, certain fire safety measures may be very useful and not so effective for the others and that the results regarding specific interventions may differ based on the group that receives it (Jonsson and Jaldell, 2020; Nilson and Bonander, 2021; Runefors et al., 2016). Smoke alarms appear most effective in fires that are not initiated by children playing with fire (Istre et al., 2002) and in properties in which, there are not any vulnerable residents present (Marshall et al., 1998). Xiong et al. (Xiong et al., 2015) noted that the consumption of alcohol or drugs by individuals most vulnerable to fire fatalities, may affect their timely response to a smoke alarm signal (Xiong et al., 2015). Thereby, additional risk protection measures may be required for individuals with physical or mental impairments or other frailties. The effects of fire and fire-related injuries for children and older adults as the most vulnerable age groups have been detailed in the literature, with an ongoing impact on children's overall quality of life and an increased risk of cardiac and cardiovascular system disease in adults (Duke et al., 2016; Duke et al., 2015).

Residential sprinkler systems are another fire safety measure that has been available for over a century. They are designed to automatically discharge water to extinguish fires, with the intent of increasing the time for building occupants to escape, reducing property damage and injuries and/or fatalities. Sprinkler systems have been successfully used in

industrial and commercial buildings for many years to protect lives and properties. However, they have only been recently mandated in residential buildings in NSW. According to the National Construction Code 2019 specifications, all new residential buildings of four storeys or more must have automatic fire sprinklers installed (National Construction Code, 2009).

Social housing is short or long-term rental accommodation for people on low incomes, especially those who have recently experienced domestic violence, homelessness or who have special needs. Social housing properties are owned by the state or territory governments and are managed by that government and/or not-for-profit agencies (Department of Communities and Justice (Dcj), 2019). In NSW, these properties are fitted with at least one hard-wired smoke alarm with a battery backup (Department of Communities and Justice (Dcj), 2017) and properties of four storeys or more are also equipped with automatic fire sprinklers. Consequently, social housing properties of less than four storeys (houses, townhouses and apartment buildings) are only equipped with smoke alarms (Housingvic, 2018) as fire risk protection.

According to the Australian Institute of Health and Welfare (AIHW), as of 30 June 2020, 95% of Australian households living in social housing had a low-income status (Australian Institute of Health and Welfare, 2020) and 4 out of 10 household in public housing had resided there for over a decade and are more likely to be unemployed compared to residences of non-social housing (Australian Institute of Health and Welfare, 2021a; Atkinson and Jacobs, 2008). Over half of the social housing occupants were female (56%) who experienced either domestic violence, relationship breakdown or financial difficulty and almost half of them were 40 years old and over and over one third of public housing tenants were aged 55 and over (Australian Institute of Health and Welfare, 2021b). Moreover, it was shown that 35% (140,900) of social housing residents in Australia had a resident with disability (Australian Institute of Health and Welfare, 2021a). In another study conducted in the state of Victoria, Australia, it was stated that around 36% of the social housing residents were born in countries other than Australia and for 14.5% of households, English was not the preferred language (Department of Human Services, 2006). In NSW, there were a total of 153,515 social housing properties at June 2021 of which 96,728 (63%) were public housing, managed by the government and included 44,335 (45.8%) apartments and 52,393 (54.2%) free-stand or semi-detached dwellings (Barnes et al., 2021).

Social housing accommodates some of the most vulnerable members of society – with a large proportion that are aged, have a long-term disability or who live with illnesses such as respiratory and cardiovascular diseases (Pawson et al., 2020). Therefore, their occupants may be at a higher risk from residential fires as their response to fire alarms may be compromised to evacuate safely in the event of a fire. The aim of this study was to identify and compare fire characteristics, building characteristics and fire response characteristics in social and non-social housing dwellings from 2005 to 2014. The average number of dwellings in NSW during that period was around 2,864,531 dwellings (Australian Bureau of Statistics, 2011) that included around 110,500 social housing properties (3.9%) (Australian Institute of Health and Welfare, 2012). Non-social housing refers to the residential properties that were not social housing and are privately owned or not owned by the state. In addition, this study aimed to identify and compare the health impact of residential fires in social and non-social housing dwellings.

2. Materials and methods

2.1. Study population, cohort identification and data sources

The study population includes all residents of NSW, which is Australia's most populous state with a population of over 8 million people (Australian Bureau of Statistics, 2021). The study cohort included all persons residing in NSW who experienced a residential fire incident

from 1 January 2005 to 31 December 2014 and reported their incident to and attended by the fire department.

Nine data sources were linked to identify emergency or health service use for each individual in the cohort. The data sources were:

- Fire & Rescue NSW (FRNSW) Australian Incident Reporting System (FRNSW AIRS), which contains information regarding fires and other incidents attended by FRNSW
- Computer-Aided Dispatch (CAD) system which contains records of all emergency calls
- NSW Ambulance (Paper-based Health Care Record (PHCR) and electronic Medical Record (eMR) that contains ambulance use data documented by clinicians
- NSW Emergency Department Data Collection (EDDC), which provides information about the presentation to the emergency department of most public hospitals in NSW
- Admitted Patient Data Collection (APDC), which includes records for all public and private hospitals
- NSW State-wide Burn Injury Service (SBIS) data, which contains details on persons admitted to Burns Units, including outpatient clinic visits, at each of the three designated Burns Units in NSW (Royal North Shore Hospital, Concord Repatriation General Hospital, or The Children's Hospital at Westmead)
- NSW Mortality data from the Registry of Births, Deaths and Marriages (RBDM) and the Australian Bureau of Statistics (ABS) Cause of Death Unit Record File (COD-URF)

The datasets and linkage have been detailed elsewhere (Harvey et al., 2020; Ghassempour et al., 2021). Ethical approval for this study was obtained from the NSW Population and Health Services Research Ethics Committee (HREC/16/CIPHS/36) and Western Sydney University Human Research Ethics Committee (RH12399).

2.2. Study variables

Residential fire incidents in NSW were studied with a focus on the key characteristics of *construction type*, *type of incident*, *the extent of fire damage*, *method of extinguishment*, and *type of detector initiating alarm*. Residential fires were identified from FRNSW AIRS data, using the *type of property* variable and properties were determined as social housing premises using the *type of owner* variable code of 'owned by state government'. Residential fire-related health service use and deaths were identified by merging FRNSW AIRS data and health data including CAD, PHCR, eMR, EDDC, APDC and SBIS and mortality data within two weeks from the date of fire incident to the date of using health services or death registrations. This two-week lag period was recommended by burn experts as some individuals might not use ambulance and health services immediately after the incident. Seeking medical help usually takes 3–7 days for moderate injuries, and an extra week is considered for less severe injuries. After two weeks from the residential fire incident, the health service use is not considered relevant to that incident.

Health data includes information such as main condition and reason for using the health services. In addition, PHCR, EDDC and APDC contain individual characteristics such as their age and gender. Using the *cause of death* variable in mortality data and 'external cause codes' (ICD-10-AM X00, X02) denoting death as a result of a fire in buildings, those who died due to residential fires within two weeks from their fire incidents were identified.

FRNSW AIRS contains fire incidents that have been attended by FRNSW and contained two subset of data with common variables and some different variables. Additionally, they had some common variables that were coded differently and therefore, contained a number of missing values that were either not reported or not applicable. In this study, we referred to them as undetermined. In addition, since the individual characteristics such as age and gender were only available in PHCR, EDDC and APDC, age and gender were missing for the ones who

used health services but did not have a record in those particular data sources and therefore, age and gender for them were undetermined.

As mentioned earlier, certain socio-economic groups such as those in social housing will to a larger degree rely on fire services whilst others will manage fires themselves and may not contact FRNSW. Therefore, in this study by referring to residential fire incidents, we refer to residential fire incidents that were attended by FRNSW.

2.3. Statistical analysis

Analysis was performed using R-3.6.0 (R Core Team, 2013). Descriptive statistics were calculated to describe the type of fire incident, fire characteristics, type of building and health service utilisation, by cohort and by social housing dwellings vs non-social housing dwellings. Residential fire incidents were given a unique ID in the AIRS data and each incident may have one or more individuals involved. Chi-square tests of independence were used to test the significance of associations. Univariate regression was conducted using log-binomial models to generate relative risk ratios and 95% confidence intervals to determine the associations between residential fires in social housing as the outcome variable and non-social housing as the reference. A Mann-Kendall trend analysis test was performed to test whether a trend was present in the proportion of fire incidents over time where no types of detectors including smoke alarms, thermal detectors, beam detectors, aspirating detectors, etc. were present. The Mann Kendall test is used for modelling or evaluating the trend present in time series and Kendall's Tau (τ) is used to understand the strength of the relationship between two variables. Negative and positive values of Tau show the downward and upward trends and p-value < 0.05 represents the trend to be statistically significant.

3. Result

Over the study period, 43,707 residential fire incidents were reported to FRNSW, involving 43,433 individuals. Of those, 5,073 (11.6%) incidents occurred in social housing properties involving 5,013 individuals.

3.1. Characteristics of residential fire incidents

Among the residential fire incidents attended by FRNSW, residential fires were more common in houses than apartments. However, residential fire incidents were almost twice as likely in apartments in social housing as in non-social housing dwellings (RR 1.85, 95%CI 1.75–1.96) (Table 1).

The risk of residential fires in structurally protected constructions was 20% higher in social housing than in non-social housing dwellings (RR 1.22, 95%CI 1.15 – 1.30). The risk of residential fire incidents for those in social housing was significantly higher due to smokers' materials (RR 1.51, 95%CI 1.34 – 1.71); open flame sources, such as matches and lighters (RR 1.62, 95%CI 1.51 – 1.74); and hot object or friction (RR 1.21, 95%CI 1.14 – 1.28) than non-social housing dwellings. The extinguishment by automatic extinguishing systems was two times higher in social housing dwellings (RR 2.02, 95%CI 1.56 – 2.57) compared to fires in non-social housing (Table 1).

The risk of residential fire occurring in a one-family or two-family dwelling was 39% lower among the fire incidents attended by FRNSW in social housing compared to non-social housing dwellings (RR 0.61, 95%CI 0.58 – 0.65). The risk of residential fires in structurally unprotected constructions was 24% lower among those in social housing than non-social housing dwellings (RR 0.76, 95%CI 0.71 – 0.81) (Table 1).

Among the fires attended by FRNSW, the risk of having fires that would extend beyond the structure of origin for social housing was 54% lower compared to non-social housing dwellings (RR 0.46, 95%CI 0.35 – 0.60). The risk of residential fires in social housing due to electrical was 60% lower (RR 0.40, 95%CI 0.36 – 0.44) and 37% lower due to fuel (RR

Table 1
 Characteristics of residential fire incidents by social vs non-social housing from 2005 to 2014, NSW, Australia.

Fire and building characteristics	Residential fire-related incidents						Social housing vs non-social housing	
	Social		Non-social		Total		RR	95%CI
	N	%	N	%	N	%		
Property type								
One-family or two-family†	2,712	53.4	25,828	66.8	28,540	65.3	0.61	0.58 – 0.65***
Apartment††	2,200	43.4	10,578	27.4	12,778	29.2	1.85	1.75 – 1.96***
Others†††	161	3.2	2,228	5.8	2,389	5.5	0.57	0.48 – 0.66***
Type of incident								
Structure & contents	1,225	24.2	9,781	25.3	11,006	25.2	0.95	0.89 – 1.01
Structure only	452	8.9	3,165	8.2	3,617	8.3	1.08	0.98 – 1.19
Contents only ~	3,266	64.4	24,541	63.5	27,807	63.6	1.03	0.98 – 1.09
Undetermined	130	2.5	1,147	3.0	1,277	2.9	0.87	0.73 – 1.04
Construction type								
Structurally Protected ^	1,646	32.4	10,682	27.6	12,328	28.2	1.22	1.15 – 1.30***
Structurally Unprotected ^^	1,063	21.0	10,234	26.5	11,297	25.8	0.76	0.71 – 0.81***
Undetermined	2,364	46.6	17,718	45.9	20,082	45.9	1.02	0.97 – 1.08
The extent of flame damage								
Confined to the object of origin	603	11.9	5,440	14.1	6,043	13.8	0.84	0.77 – 0.91***
Confined to the structure of origin #	1,917	37.8	14,082	36.4	15,999	36.6	1.05	0.99 – 1.11
Beyond the structure of origin	51	1.0	886	2.3	937	2.1	0.46	0.35 – 0.60***
Others ##	193	3.8	1,191	3.1	1,384	3.2	1.21	1.05 – 1.38*
Undetermined	2,309	45.5	17,035	44.1	19,344	44.3	1.05	1.00 – 1.11*
Form of Heat of Ignition								
Fuel-Fired	492	9.7	5,884	15.2	6,376	14.6	0.63	0.57 – 0.69***
Electrical	388	7.6	7,174	18.6	7,562	17.3	0.40	0.36 – 0.44***
Smokers' Materials	272	5.4	1,305	3.4	1,577	3.6	1.51	1.34 – 1.71***
Open Flame, Matches and Lighters	890	17.5	4,179	10.8	5,069	11.6	1.62	1.51 – 1.74***
Hot Object or Friction	1,709	33.7	11,232	29.1	12,941	29.6	1.21	1.14 – 1.28***
Spreading from another Hostile Fire	226	4.5	1,934	5.0	2,160	4.9	0.90	0.78 – 1.02
Others §	136	2.7	1,178	3.0	1,314	3.0	0.89	0.75 – 1.04
Undetermined	960	18.9	5,748	14.9	6,708	15.3	1.29	1.21 – 1.37***
Detector initiating alarm								
No detector installed	4,457	87.9	34,937	90.4	39,394	90.1	0.79	0.73 – 0.86***
Had some type of detectors	598	11.8	3,592	9.3	4,190	9.6	1.26	1.16 – 1.36***
Undetermined	18	0.4	105	0.3	123	0.3	1.26	0.79 – 1.86
Extinguishment method								
Self-Extinguished	515	10.2	4,273	11.1	4,788	11.0	0.92	0.84 – 1.00
Manual Fire Fighting Aids ‡	1,235	24.3	9,529	24.7	10,764	24.6	0.98	0.92 – 1.05
Fire Extinguisher ††	2,794	55.1	21,288	55.1	24,082	55.1	1.00	0.95 – 1.05
Automatic Extinguishing System †††	63	1.2	207	0.5	270	0.6	2.02	1.56 – 2.57***
Other extinguishment method ††††	406	8.0	2,606	6.7	3,012	6.9	1.18	1.07 – 1.29**
Undetermined	60	1.2	731	1.9	791	1.8	0.65	0.50 – 0.82**
Sprinkler presence								
Present	63	1.2	333	0.9	396	0.9	1.38	1.06 – 1.75*
Not present	2,707	53.4	21,410	55.4	24,117	55.2	0.93	0.88 – 0.98*
Undetermined	2,303	45.4	16,891	43.7	19,194	43.9	1.06	1.00 – 1.12

Significance (p value) = * < 0.01, ** < 0.001, *** < 0.0001.

† Private dwellings and duplexes each occupied by members of a single-family group, with total sleeping accommodation for not more than 20 persons, with rooms rented to no more than two outsiders per living unit. This included one-family dwelling: year-round use, one-family dwelling: seasonal use, two-family dwelling: year-round use, two-family dwelling: seasonal use, and one-family and two-family dwelling not classified above and insufficient information to classify further.

†† Quarters for families living independently of each other and with kitchen facilities in individual units, whether designated as an apartment house, garden apartment, living unit, condominium apartment, flat or by any other name. This includes one or two living units with business, three to six living units, seven to 20 living units, over 20 living units and apartments, living units, flats not classified above or insufficient information to classify further.

††† includes rooming/boarding/lodging houses, hotels/motels/lodges, dormitories, holiday apartments/self-contained units and other residential occupancies.

~ includes Foodstuffs burnt, confined to cooking equipment.

^ includes Structurally Fire Resistant, Structurally Protected Non-combustible, Structural Protected Combustible and Protected Lightweight Framing.

^^ includes Structurally Unprotected Combustible (moderate), Structurally Unprotected Non-combustible, Structurally Unprotected Combustible (ordinary), Unprotected Lightweight Framing and Combustible Building.

includes confined to part of room or area of origin, confined to the room of origin, confined to the floor of origin and confined to the structure of origin.

includes no damage of this type, the extent of the damage not classified above.

§ includes heat from explosives/fireworks, heat from a natural source, other forms of heat of ignition such as microwaves.

|| includes thermal detector remotely monitored and thermal detector not remotely monitored, smoke detector remotely monitored and smoke detector not remotely monitored, detector remotely monitored, flame detector not remotely monitored, multifunction detector and other detector types.

‡ includes shovels, fire blanket, garden hose and beaters.

†† includes portable fire extinguisher, appliance hose lines with water carried in appliance tanks, hose lines with water direct from hydrant, stand-pipe, hose lines with water from pump and monitor nozzle.

††† includes Sprinkler systems, Gaseous fire suppression which uses inert gases and chemical agents to extinguish a fire as well as, Condensed aerosol fire suppression which is powder automatic extinguisher, used where electrical fires are prevalent.

†††† includes major method of extinguishment not classified above and insufficient information to classify further.

0.63, 95%CI 0.57 – 0.69) compared to non-social housing dwellings. The risk of fires in properties without functioning fire detectors was 21% lower in social housing compared to non-social housing dwellings (RR 0.79, 95%CI 0.73 – 0.86) (Table 1).

Over the study period, the proportion of residential fire-related incidents in buildings that did not have any type of functioning fire detectors showed a statistically significant downward trend, ranging from 91.8% in 2007 to 87.9 in 2013, ($\tau = -0.7$, $p\text{-value} = 0.004$). Fig. 1, shows that the changes from 2005 to 2010 were not significant. However, from 2010 to 2013 there was a significant reduction in the proportion of residential fire incidents in residences where no functioning detector was present.

3.2. The health impact of residential fire-related incidents in social housing and non-social housing dwellings

There were 2,388 fires that resulted in the use of one or more health services, including ambulance, emergency department, hospital and burns clinics. There were 118 residential fire-related deaths, which equates to 27 residential fire-related deaths per 10,000 residential fire events in NSW. Among the fires attended by FRNSW, the proportion of fatal residential fire-related incidents did not differ significantly in social and non-social housing. The risk of residential fire incidents that resulted in health service utilisation or hospital admission was 16% (RR 1.16, 95%CI 1.04 – 1.28), and 25% (RR 1.25, 95%CI 1.02 – 1.51), higher for fires in social housing compared to non-social housing dwellings, respectively (Table 2).

Only 1% of the properties that experienced a residential fire incident were equipped with sprinkler systems, and 73.7% of the incidents that resulted in the use of health services occurred where no sprinklers were present. The risk of having a residential fire-related incident that resulted in health service utilisation was more than double in the absence of sprinkler systems compared to those fire incidents that did not result in the use of health services (RR 2.27, 95%CI 2.08–2.48). (Table 3).

3.3. Demographic characteristics of the residents who used health services in social housing and non-social housing dwellings

The proportion of residential fire incidents for individuals who used health services, regardless of whether the fire occurred in social or non-social housing was similar between males and females (39.0% vs 37.7%). Among the residential fire incidents attended by FRNSW, the risk of having a residential fire that resulted in the use of health services increased by 40% for those aged 25–65 (RR 1.40, 95%CI 1.14 – 1.73)

and decreased by 34% for those 65 years of age and older in social housing compared to non-social housing dwellings (RR 0.66, 95%CI 0.48 – 0.89) (Table 4).

Moreover, multiple logistic regression analyses revealed that property type (one-family or two-family dwellings, apartments), form of heat of ignition (smokers’ materials, open flame, matches and lighters, hot object or friction) and extinguishment method (automatic extinguishing system) were risk factors for residential fire incidents in social housing (see Table S1 for details).

Comparing the residential fire incidents in social housing and non-social housing that occurred in apartments, it was shown that the risk of residential fire incidents that required health service utilisation or hospital admission was 49% and 74% higher in social housing apartments compared to the apartments in non-social housing. In addition, the risk of fire incidents in apartments that damaged both structure and contents were 17% higher in social housing and they were 77% more likely to be extinguished by automatic extinguishing systems. For those younger than 25 years old, the risk of using health services as a result of residential fire incidents was 70% lower for social housing residents in apartments compared to non-social housing (see Table S2 and Table S3 for details).

4. Discussion

This study has quantified the impact of residential fires in social housing and non-social housing dwellings using FRNSW data. Over the study period, 43,707 residential fire incidents were reported to FRNSW involving 43,433 individuals. Among the total fire incidents attended by FRNSW, 5,073 of those fire incidents occurred in social housing dwellings involving 5,013 individuals indicating how some individuals were involved in more than one fire incident.

Studies internationally and in Australia have concluded that vulnerable populations are more likely to experience the negative impacts of residential fire incidents (Duke et al., 2016; Duke et al., 2015; Smith et al., 2018; DiGuseppi et al., 1998). In this study, we compared residential fire incidents and identified factors associated with fire incidents in terms of fire characteristics, building characteristics and individual characteristics for those living in social housing compared to non-social housing dwellings. In addition, we examined the health impact of residential fire-related incidents in terms of using health services, hospital admission and mortality in social and non-social housing dwellings at the population level in NSW for 10 years.

Our results concur with previous studies and demonstrate that residential fires in NSW mostly occurred in one-family or two-family dwellings with those aged between 25 and 65 years of age. However,

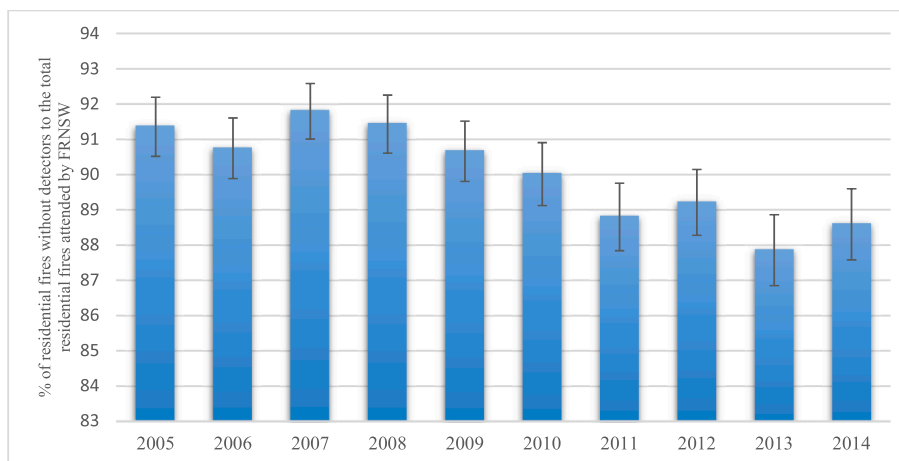


Fig. 1. The proportion of residential fire incidents where there was no functioning type of detector present to the total number of residential fire incidents attended by FRNSW with 95% CI range per year from 2005 to 2014.

Table 2

Residential fire-related incidents health impact characteristics in social housing dwellings and non-social housing dwellings from 2005 to 2014, NSW, Australia.

Characteristics	Residential fire-related incidents						Social housing vs non-social housing	
	Social		Non-social		Total		RR	95%CI
	N	%	N	%	N	%		
Health services †								
Used	318	6.3	2,070	5.4	2,388	5.5	1.16	1.04 – 1.28*
Hospitalisation								
Hospitalised	100	2.0	593	1.5	693	1.6	1.25	1.02 – 1.51*
Mortality status								
Died	12	0.2	106	0.3	118	0.3	0.88	0.47 – 1.47

† includes using Ambulance, Emergency department, Hospital and Burn clinics as a result of residential fire incident. Significance (p value) = * < 0.01, ** < 0.001, *** < 0.0001.

Table 3

Residential fire incidents characteristics and relative risk of residential fires that resulted in health service utilisation and those that did not result in health service utilisation based on presence or absence of sprinkler systems from 2005 to 2014, NSW, Australia.

Characteristics	Residential fire-related incidents						Social housing vs non-social housing	
	Social		Non-social		Total		RR	95%CI
	N	%	N	%	N	%		
Sprinkler system								
Present	11	0.5	385	0.9	396	0.9	0.51	0.26 – 0.86*
Not present	1,759	73.7	22,358	54.1	24,117	55.2	2.27	2.08 – 2.48***
Undetermined	618	25.9	18,576	45.0	19,194	43.9	0.45	0.41 – 0.49***

Significance (p value) = * < 0.05, ** < 0.001, *** < 0.0001.

Table 4

Residential fire-related incidents that resulted in health service utilisation in social housing dwellings and non-social housing dwellings based on residents' demographics from 2005 to 2014, NSW, Australia.

Demographic Characteristics	Residential fire-related incidents						Social housing vs non-social housing	
	Social		Non-social		Total		RR	95%CI
	N	%	N	%	N	%		
Gender								
Female	133	41.8	767	37.1	900	37.7	1.19	0.96 – 1.46
Male	115	36.2	816	39.4	931	39.0	0.89	0.71 – 1.09
Undetermined	70	22.0	487	23.5	557	23.3	0.93	0.72 – 1.18
Age								
<25	20	6.3	169	8.2	189	7.9	0.78	0.49 – 1.16
25–65	183	57.6	990	47.8	1,173	49.1	1.40	1.14 – 1.73*
65+	43	13.5	414	20.0	456	19.1	0.66	0.48 – 0.89*
Undetermined	72	22.6	497	24.0	569	23.8	0.94	0.73 – 1.19

Significance (p value) = * < 0.01, ** < 0.001, *** < 0.0001.

among the fires that were attended by FRNSW, those aged 65 years and above in social housing had a lower risk of using health services as a result of residential fire incidents. This may mean that fires that had elderly involved were less severe and extinguished before causing serious damage, death or injuries. In addition, it may also suggest that home safety programs delivered specifically for the elderly, such as the SABRE (Smoke Alarm Battery Replacement for the Elderly), has been functional (Tannous and Agho, 2019). As shown in Table 4, age category for almost 20% of the individuals who used residential fire-related health services was undetermined and therefore, our result may be affected by the missing data. The undetermined values increased the length of the confidence intervals and degree of uncertainty, which indicates that very little is known about the effect and a larger study is needed to generate a more precise estimate of effect. The input of the data is based on the FRNSW personnel best estimate of ownership. The list of property owned by the NSW state agency has not, and is not currently, linked to the FRNSW AIRS data resulting in the potential for misclassifications of the ownership of the property.

The result of extinguishment method in relation to all the dwellings as well as in relation to apartment only, showed that the residential fires

attended by FRNSW were more likely to be extinguished by automatic extinguishing systems in social housing compared to non-social housing with the premises impacted being less likely to be structurally unprotected, emphasizing that apartments in social housing compared to non-social housing are well equipped, complying with the regulations.

Fires in social housing were less likely to extend beyond the structure of origin but despite that, this study showed that the incidents in social housing were more likely to require using health services or hospital admissions. These figures may be an underestimate of the true number of incidents and associated health services use as identification of social housing was based on state ownership in 'type of owner' variable in the AIRS data. In addition, this study showed that the presence of sprinklers, which has been shown to be the most effective for vulnerable people with disability or under influence of drugs and/or alcohol compared to smoke alarms (Xiong et al., 2015), decreased the risk of having a residential fire incident that required using health services. Our findings are in accordance with previous studies suggesting effectiveness of sprinklers compared to other fire safety measures.

This study further concluded that the fire incidents in social housing properties were more likely due to smokers materials and open flame

and matches and these fires have been associated with fatal fire incidents (Xiong et al., 2017). Moreover, fire incidents were less likely to be confined to the object of origin (i.e. more likely to extend beyond the object of origin but were confined to the structure of origin) and this may emphasize the importance of having sprinkler systems installed in those properties to prevent fires from growing and spreading.

Other factors of note are human behaviour, and individual occupants' cognitive and physical abilities, however, these variables were not available in the AIRS data and therefore were not able to be investigated as part of this study. In 2020, around one-fifth of people living in social housing were recognised with disabilities (Australian Institute of Health and Welfare, 2020), and they are at greater risk of experiencing a residential fire. In addition, persons who are smokers, use alcohol and/or substances, and are habitual hoarders have a higher risk of fire (Friesinger et al., 2019). These behaviours are over-represented in social housing when compared to private housing. This needs to be recognised in the provision of active or passive risk protections by the state in their properties.

Protective measures, such as the installation of smoke alarms, have been mandated in many countries, including Australia and have been attributed to the reduction in fire incidents that require fire brigade attendance (Ahrens, 2013; Gilbert, 2021; Greene and Andres, 2009; Chubb, 2003). As a protective measure and its beneficial impacts, the installation of fire sprinkler systems in reducing injuries and deaths in residential fire incidents have also been demonstrated (Garis et al., 2017; Garis and Clare, 2013; Wales, 2017; Butry et al., 2007; Butry, 2009; Banfield et al., 2015; Benichou et al., 1999; Association, 2011).

The current regulatory requirement for risk protection in NSW is an operational smoke alarm to be installed. This study demonstrated that those in social housing apartments were almost two times more likely to report residential fire incidents than those in non-social housing apartments. While smoke alarms were more present in social housing than non-social housing, many were identified to be non-operational with the removal of batteries and/or the entire unit.

Since the mandated requirements to have an operational smoke alarm in all residential buildings, the number of residential fire incidents without detectors have decreased from 4,360 in 2007 to 3,473 in 2014. Despite this, we found that more than 90% of the residential fire incidents occurred in properties that did not have an operational smoke alarm or any other type of fire detectors. This emphasizes the importance of targeting high-risk households and home fire safety checks programs, which provide fire safety education and install smoke alarms and ensure their functionality (O'grady, N., 2014; Tannous et al., 2018).

Automatic sprinklers provide an intervention to control or extinguish a fire that can significantly improve the survivability of occupants in house fires. Research conducted by FRNSW into the performance of residential sprinklers demonstrated that sprinklers have a significant effect on heat and atmospheric tenability within the structure (Wales, 2017). In addition to helping the victims, automatic fire sprinklers also protect and reduce firefighter injury and their respective costs. A study in British Columbia, Canada, showed the injury rate for firefighters was doubled in buildings that did not have automated fire sprinklers (Garis et al., 2017). Sprinklers might also help mitigate higher call volumes that lead to increased response times, more emergency personnel and potentially improve the efficient use of fire department resources. Some studies argued cost effectiveness of sprinkler systems in one-family, two-family dwellings and some have demonstrated solutions to reduce its cost (Beever and Britton, 1999; Poh and Bennetts, 2005; Jaldell, 2013).

In NSW, sprinklers are compulsory in all new shared residential dwellings above three levels in height which can remarkably protect the residents and prevent fire spread in dwellings next door which are usually apartments and home to many families. However, considering the characteristics of the residents in social housing properties, if the risk protection extended to having a sprinkler system installed in one-family and two-family dwellings, this would provide greater protection to the most vulnerable groups and allow them time to save themselves and

those they want to protect.

5. Limitations

Some limitations were identified with the study. One of the limitations of this study is use of fire brigade administrative data that has comprehensive data on the built structure but limited on residents' characteristics. Thereby, this constrained the analysis on residents' socio-economic indicators in social and non-social housing dwellings. FRNSW AIRS contains fire incidents that have been attended by FRNSW and there was a change in the platform for and coding of reporting and for NSW the latest figures available was 31 March 2015 and for the study we used a 10-year period from 2005 to 2014 for consistency in reporting the data. The process of linking the different datasets and obtaining appropriate data custodians' approval also results in significant delay. Additionally, in NSW and Australia more broadly, there has not been any major regulatory changes that would affect the building standards or the appliances/furniture, etc. and so the data in this study is still relevant. In addition, the 'type of owner' and the use of 'owned by state government' for social housing was based on assessments by the brigade. A list of properties owned by the state and are of the different types of housing would have been ideal for matching the addresses of fire incidents in FRNSW AIRS data.

There are other important factors relevant to the outcome of fire incidents such as the weather condition and locating the place that affect response time of the fire and emergency response services and many studies have indicated the relationship between long response time with worse outcomes (Lucchese, 2020). Future studies may explore the fire brigade response time and its impact in terms of fire damage to the construction and its health outcome for social and non-social housing dwellings. Furthermore, in future studies using community housing data linked to FRNSW AIRS and health administrative data may provide a comprehensive overview of individual characteristics in addition to fire and building characteristics in social and non-social housing dwellings.

Another limitation was that only fire incidents that were reported to FRNSW and the health impact of those incidents within two weeks from the fire incident were used for this study. Fire incidents that were not reported to or attended by FRNSW were not included in this study. This suggests that the burden of deaths and injuries associated with residential fire incidents are an underestimated of the true number as demonstrated by the authors elsewhere (Ghassempour et al., 2021).

6. Conclusion

Our analysis suggest that the risk of residential fire incidents and associated injuries is higher for residents in social housing. The form of heat of ignition was identified as an important factor in increasing the risk of residential fires in those properties. Implementing new policies for fire safety in social housing residences is essential to eliminate the unfortunate health impacts and consequent costs of residential fires. Future studies may explore other residential fire-related policies impact on the safety of residents.

6.1. Policy implications of findings and implications for future research

The findings of this study reaffirm the importance of prevention initiatives such as installing fire sprinkler systems as they significantly improve the safety of occupants in the event of a fire. For social housing properties, and the demonstration of increased residential fire incidents with associated injuries and/or mortalities, the owners of the property have a duty of care to install fire sprinkler systems. These systems would enhance the risk protection to the most vulnerable group. For non-social housing, nudge techniques of providing reduced general insurance premiums, home and/or contents, one of the state-based grants to incentivise non-social housing to install automatic fire sprinkler systems. Future studies may explore the economic benefit of installing fire

sprinkler systems in social housing residences.

CRedit authorship contribution statement

Nargess Ghassempour: Data curation, Formal analysis, Methodology, Writing – original draft. **W. Kathy Tannous:** Conceptualization, Resources, Supervision, Writing – review & editing. **Kingsley E. Agho:** Supervision, Methodology, Writing – review & editing. **Gulay Avsar:** Supervision, Methodology, Writing – review & editing. **Lara A. Harvey:** Supervision, Resources, Methodology, Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Institutional review board statement

Ethics approval for this study was provided by the NSW Population and Health Service Research Ethics Committee (HREC/16/CIPHS/36) and Western Sydney University Human Research Ethics Committee (RH12399).

Informed consent statement

Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research and patient consent was not required.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.pmedr.2022.101860>.

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