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INJURIES AND FATALITIES IN FIRES: A CONTINUUM?

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ABSTRACT

Models of human behaviour in fires either ignore injuries or assume that they are a step or two away from fatalities, and concentrate on predicting evacuation and fatalities. This paper looks at evidence from residential building fires to explore continuities and discontinuities between civilian injuries and fatalities. Factors involved in injury and fatality relate directly to characteristics and behaviour of occupants and suggest major differences between the two types of casualty including age, gender, location of the fire, type of injury, and response to the fire. There are sufficient differences to warrant caution in assuming that fatalities form part of the same spectrum as non-injury and injury.

INTRODUCTION

The prediction of fatalities resulting from fires, and the proportion of occupants who survive fires, is the primary focus of occupant response models for performance-based assessment of fire safety design. In line with what is known about the majority of fire casualties, it is possible to calculate the time at which conditions in any area reach a pre-defined state of untenability or, in more sophisticated models, the effects of fire products (usually heat and/or gases) on occupants over time. There may also be included a pre-fatality incapacitation stage in which progress towards fatality can only be interrupted by events such as rescue or fire control.

It would be useful if models were able to predict fire injury as well as fatality because death is not the only human cost of fires. While the range of injuries from fire is broad and includes psychological distress as well as physical damage, smoke and/or thermal injuries are the most frequently observed and relate directly to fire. A convenient solution for predicting injury would be to use the same criteria as that used for predicting fatality but with lower values. However, the validity of such a solution could be questioned.

METHODOLOGY

This study reviews what is known about fire injuries and, using evidence from residential fires in apartment buildings, and from coronial files on residential fire deaths. The study also highlights *some* of the continuities and discontinuities between civilian injuries and fatalities.

The U.S. National Fire Incidence Reporting System (NFIRS) is probably one of the most useful sources of data on injuries at present. It makes up in quantity for any lack of finer detail that intensive investigations may produce. Coroner files that are useful in developing understanding of fatalities do not do the same service for injuries although they may make occasional reference to injured persons. In any case, the majority of fire injuries occur in non-fatal fires as will be shown. Research on the occurrence of fires in general (i.e. reported and non-reported fires) provides little if any information on injuries.

Unless otherwise stated, the NFIRS statistics used refer to occupant injuries and fatalities resulting from apartment fires for a ten-year period between 1983 and 1993 (excluding 1986). The NFIRS fire incident database includes 420315 fires, 28635 injuries and 3111 fatalities. For every 1000 fires in apartment buildings, there are 68 injuries (from 47 fires) and 7 deaths (from 6 fires). The NFIRS injuries database contains information on casualty fires and the characteristics and behaviour of casualties. Unavoidable limitations result from restricting data collection to casualties, as there is no information on uninjured occupants from casualty fires or from the non-casualty fires which make up the bulk of residential fires. The absence of information on those who avoid injury in fires means that findings about injuries and fatalities cannot be generalised to all people who experience a fire. Nonetheless, they may help to generate hypotheses about the parent population.

The complexity of this subject has been recognised, however multivariate analysis at this exploratory stage has not been introduced. Injuries and fatalities are compared by a ratio of injuries to fatality (*I/F* ratio). Thus, a high number indicates few fatalities and a low number indicates many fatalities compared with injuries. Most tables also show the proportion of injuries and the proportion of fatalities falling within any category. Missing data variously reduce the sample size as there is no attempt in this study to adjust data to include 'unknown' cases. 'Unknown' cases are given for completeness but are ignored for analysis. In addition, categories have been selected with the highest frequencies and remaining cases are lumped under 'other'.

RESULTS

Frequency of injuries and fatalities

Table 1 distinguishes fires by fatality and injury and shows that about 96% of injury fires are non-fatal fires (1642/2420) and 68% of fatal fires have no recorded injuries (18941/19719). Nevertheless, there is a relationship between injuries and fatalities as there are 39 fatal fires for every 1000 fires where injury occurs and 321 injury fires for every 1000 fatal fires, both about seven times the overall rates of 6 fatal fires and 47 injury fires per 1000 fires.

Table 2 looks specifically at the 2420 fatal fires to explore the relationship between injuries and fatalities but fails to display any clear linear pattern. The high rate of injury to fatality where there are five or more fatalities is heavily influenced by two fires, one with 6 deaths and 52 injuries, the other with 16 deaths and 15 injuries – a pointer to the unreliability of smaller samples.

The frequency of injury may reflect the availability of personnel to provide assistance at the scene of the fire. However, it appears that the injuries listed in the NFIRS database are not trivial as 75% of the injured were taken to hospital. An unknown proportion of those taken to hospital may die before admission or shortly thereafter – the picture from coroners' records (not from the U.S.) is that there are regional differences in the proportions who reach hospital.

Table 1: Association between injuries and fatalities.

		Fires with		
		no injuries	injuries	Total fires
Fires with	no fatalities	398954	18941	417895
	fatalities	1642	778	2420
Total		400596	19719	420315

Table 2: Association between injuries and fatalities – fatal fires only.

	Fatal fires with		Total		
	no injuries	injuries	Injuries	Fatalities	I/F ratio
1 fatality	1421	579	1300	2000	0.7
2 fatalities	147	126	338	546	0.6
3 fatalities	46	45	113	273	0.4
4 fatalities	14	9	21	92	0.2
5 fatalities	12	10	30	110	0.3
>5 fatalities	2	9	97	90	1.1
	1642	778	1899	3111	0.6

Nature of injury in fires

The precipitating causes of injury and fatality from NFIRS statistics are summarised in Table 3 and the 'Exposure to fire products' category is expanded in Table 4. The majority of casualties result from exposure to fire products (83% of injuries and 90% of fatalities). Of this group, smoke and burns are implicated in 17% of injuries and 71% of fatalities, and smoke alone in 57% of injuries and 24% of fatalities (Table 4) - reverse images. Smoke and smoke and burn injuries also feature in sub-categories of the other causes listed in Table 4 but space precludes detailing them here.

Smoke injury in isolation from burn injury, as the cause of fatality, may be more common than shown by NFIRS. Bowes[2] and Anderson et al.[1] on the basis of coroners' findings, which have the advantage of forensic evidence that may also distinguish post-mortem burns, suggest that about half of all fire fatalities may be due to smoke inhalation alone. Table 5 presents data on the immediate cause of fatality for 286 consecutive cases of residential fire deaths (suicides omitted) which suggests a similar proportion. The cases are from the Coroners' courts in Melbourne, Vancouver and London. If the 'trauma' cases are excluded (the people who die from a range of complications after being injured) deaths due to smoke injury would increase to 64%.

The *I/F* ratio in Table 3 shows, not surprisingly, that being caught by or trapped by the fire greatly increases the likelihood of fatality, that falls are more likely to result in injury and that injury far exceeds fatality where contact (presumably with objects affected by the fire) occurs. Table 4 shows a marked contrast in outcome between burn injuries and smoke and burn injuries, with the former resulting in a much higher ratio of injury to fatality. It is likely that this, and the contact injuries also, reflects the active responses of injury victims to fire (shown below).

Table 3: Cause of casualties (% of total injuries/fatalities in italics).

	Injuries	*%*	Fatalities	*%*	*I/F* ratio
Exposure to fire products	18443	*83.1*	2237	*90.3*	8
Contact (rubbed by etc)	1287	*5.8*	8	*0.3*	161
Falls & stepping on etc	968	*4.4*	19	*0.8*	51
Caught or trapped	408	*1.8*	163	*6.6*	3
Other	1079	*4.9*	50	*2.0*	22
Total known	22185	*100.0*	2477	*100.0*	9
Unknown, not available	6346		630		

Table 4: Cause of casualties – details of 'Exposure to fire products' in Table 3.

	Injuries	*%*	Fatalities	%	*I/F* ratio
Smoke	10359	*57.4*	503	*23.7*	21
Burns	4357	*24.2*	111	*5.2*	39
Smoke and burns	3012	*16.7*	1500	*70.6*	2
Other	314	*1.7*	11	*0.5*	29
Total known	18042	*100.0*	2125	*100.0*	9
Unknown, not available	401		112		

Table 5: Coroner findings re immediate cause of death (residential fire fatalities).

Immediate cause of death	Frequency	%
Smoke inhalation	122	53.8
Smoke and burns	36	15.8
Burns	31	13.7
Trauma, complications post-incident	38	16.7
Total known	227	100.0
Undetermined	59	

Age

Table 6 combines age and gender data and details the age groups to highlight noteworthy differences between injuries and fatalities – also seen in Figure 1. The injury/fatality ratio varies substantially with age, more so than with gender. It is known that the oldest and youngest age groups have the highest number of fatalities with frequencies well outside that expected on a population basis. Evidence here shows that the same phenomenon is also apparent for injuries.

Table 6 shows other important trends including:

1. Of those aged 15-39 years, about 40% of the general US population in 1990 represent half (50.5%) of the injuries but only a quarter (25.6%) of the fatalities. The over-representation holds true for both females and males although there are more males injured overall. People in this age group can be assumed to have better health, mobility and independence than others, all factors that would argue for reduced vulnerability, so the injury rate is remarkable. It is referred to later in the context of the behaviour of casualties.

2. There is a gender difference in the *I/F* ratio for adults with women less likely to become fatalities. The marked difference in male and female fatality rates is less evident for injury. There are 51% more male than female deaths (increasing to a staggering 72% if the 70+ age group is excluded to avoid the female bias among older people), but only 12% more male than female injuries (22% if those aged 70+ are excluded).

Table 6: Casualties by age and gender.

Age group	Injuries		Fatalities		*I/F* ratio Female	*I/F* ratio Male
	Female	Male	Female	Male		
0-4*	1182	1575	241	329	5	5
5-9	347	476	59	93	6	5
10-14	329	382	33	39	10	10
15-19	644	638	30	30	22	21
20-24	1406	1574	62	96	23	16
25-29	1306	1657	47	99	28	17
30-34	1007	1430	56	100	18	14
35-39	733	990	32	111	23	9
40-44	537	692	48	87	11	8
45-49	383	416	38	84	10	5
50-54	331	363	36	62	9	6
55-59	295	342	33	74	9	5
60-64	335	321	45	106	7	3
65-69	343	295	48	77	7	4
70+	1352	658	222	176	6	4
Total	10530	11809	1030	1563	10	8
Unknown, n/a	750	944	44	70		

* Re '0' years: may include some of unknown age mistakenly classified.

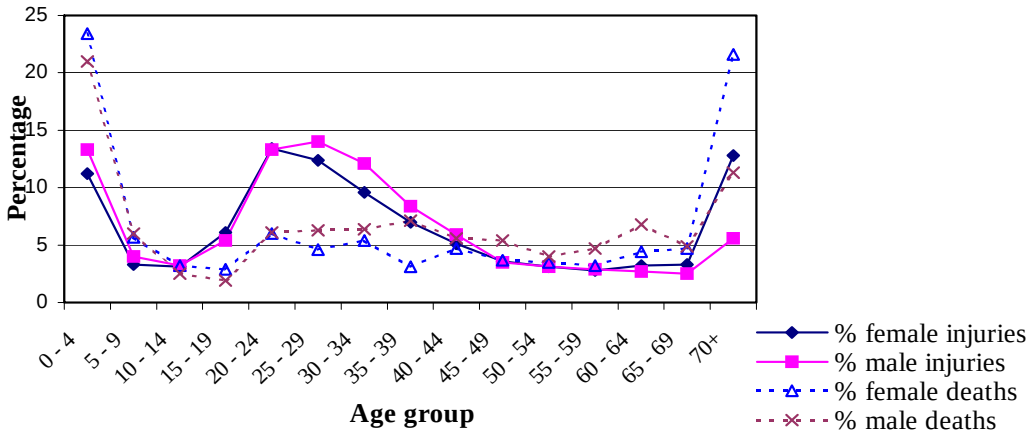

Figure 1: Proportions of casualties by age and gender.

Time of occurrence

Table 7 gives the time of occurrence of injuries and fatalities in 3-hour groups with the associated number of fires and rates of injury and fatality per 1000 fires. The peak period for injury and fatality per 1000 fires is 1-4 am, and the majority of fatalities (52%) occur between 10 pm and 7 am, when the injury to fatality ratio is lowest. There is less variation in the spread of injuries than of fatalities. A comparison between the lowest and highest frequency rates per 1000 fires shows that injuries double but fatalities increase by a factor of six. Time of day is important because it affects the type and frequency of ignitions (eg. the sharp reduction in fires in the early morning hours) as well as the likelihood of occupants being asleep.

Ignition factor

Proportions of injuries and of fatalities and ratios of injury to fatality vary considerably according to the ignition factor. Table 8 orders the most frequently occurring ignition factors for injury by injury and adds a descriptor of the most frequent behaviour in the NFIRS sub-category. Ignition factor is not entered for a large proportion of fires. Furthermore, there are problems arising from the failure to have categories that are mutually exclusive.

Ignition factor produces some significant variations in the *I/F* ratio. Smoking materials are the leading cause of both types of casualty and the *I/F* ratio of 7 is relatively low. The second most frequent category for injury, operational deficiency - unattended, has by contrast a very high *I/F* ratio. From other evidence in the database, it seems that many of these fires are located in kitchens and involve cooking activities, so being out of the room provides a significant advantage. Fires started by children playing with matches and the like contribute in similar proportions to both injury and fatality.

Table 7: Casualties by time of day (% of total injuries/fatalities in italics).

	Fires	Injuries	%	Fatalities	%	*I/F* ratio	Injuries/ 1000 fires	Fatalities/ 1000 fires
7.01am - 10am	35670	3342	*12.3*	327	*11.2*	10	94	9.2
10.01am - 1pm	54816	3649	*13.4*	311	*10.7*	12	67	5.7
1.01pm - 4pm	62393	3176	*11.7*	235	*8.1*	14	51	3.8
4.01pm - 7pm	75430	3824	*14.0*	255	*8.7*	15	51	3.4
7.01pm -10pm	72634	3978	*14.6*	279	*9.6*	14	55	3.8
10.01pm - 1am	53832	4105	*15.1*	538	*18.4*	8	76	10.0
1.01am - 4am	25006	2596	*9.5*	494	*16.9*	5	104	19.8
4.01am - 7am	26608	2562	*9.4*	479	*16.4*	5	96	18.0
Total	406389	27232	*100.0*	2918	*100.0*	9		

Table 8: Casualties by ignition factor (% of total injuries/fatalities in italics).

	Injuries	%	Fatalities	%	*I/F* ratio
1 Abandoned material (includes smoking related fires)	3817	*16.4*	581	*26.2*	7
2 Operational deficiency – unattended (includes cooking fires)	3707	*15.9*	90	*4.0*	41
3 Children playing	3193	*13.7*	290	*13.1*	11
4 Incendiary	2023	*8.7*	300	*13.5*	7
5 Suspicious	1878	*8.1*	205	*9.2*	7
6 Falling asleep	1803	*7.7*	244	*11.0*	7
7 Misuse of heat of ignition	1063	*4.6*	*107*	*4.8*	9
8 Combustibles too close to heat	1239	*5.3*	103	*4.6*	12
9 Short circuit, ground fault	1147	*4.9*	73	*3.3*	16
10 All other known categories	3431	*14.7*	228	*10.3*	18
Total known	23301	*100.0*	2221	*100.0*	11
Unknown, not available	5230		886		

Casualty disposition and behaviour prior to fire and in response to fire

There is considerable evidence from coronial sources that the characteristics and behaviour of people who die in fires relates directly to involvement with ignition[3]. Whether the same pattern holds for people who are injured is less clear because of the reliance on fire statistics alone. There is no independent source of evidence to confirm the statistics. Coroner information indicates a substantial margin of error in estimates for some NFIRS variables for fatalities (e.g. the overestimation of burns as contributing to fatalities, or the underestimation of the role of alcohol abuse.). It cannot be assumed that the same uncertainties apply to injuries when there are other significant differences between the two types of casualty.

The first variable considered is casualty location at the time of ignition (Table 9). Data from the aforementioned coroners' records indicate that most fatalities are from the room of fire origin – excluding suicides, 64% of 182 cases from houses, units, apartments, flats and bed-sits were initially in the room of fire origin and the proportion increases to 80% if just the 39 cases from apartments, flats and bed-sits are considered. NFIRS indicates that about half of the fatalities were close to the fire at ignition, that is, either engaged with ignition or in the same room, and about 40% of the injured were close to the fire at ignition, but this may be an underestimation. Apart from this difference and the 5% difference in being on the premises at the time of ignition, the two groups are very similar and location at ignition does not differentiate between injuries and fatalities.

Table 9: Location at ignition (% of all injuries/fatalities in italics).

	Injuries	*%*	Fatalities	*%*	*I/F* ratio
Intimately involved	3259	*15.2*	539	*22.1*	6
In room of fire origin	5971	*27.8*	657	*26.9*	9
On level of fire origin	5615	*26.2*	663	*27.2*	9
In building	5357	*25.0*	562	*23.0*	10
Off property	1239	*5.8*	19	*0.8*	65
Total known	21441	*100.0*	2440	*100.0*	9
Unknown, n/a	7090		667		

Table 10 shows the personal state of the casualties at the time of ignition. Unlike the victims of fatal fires, of whom over 80% are asleep or incapacitated in some way, whether temporarily or permanently, half of the people who are injured are reported to be awake and apparently unimpaired about the time of the fire start. This factor is a prime differentiator between injuries and fatalities.

Table 10: Casualties by condition at ignition (% of all injuries/fatalities in italics).

	Injuries	*%*	Fatalities	*%*	*I/F* ratio
Awake, unimpaired	10352	*53.2*	287	*16.5*	36
Asleep	6845	*35.1*	898	*51.6*	8
Too young/old to act	1085	*5.6*	262	*15.0*	4
Impaired by drugs	878	*4.5*	194	*11.1*	5
Bedridden	296	*1.5*	97	*5.6*	3
Other	20	*0.1*	3	*0.2*	7
Total known	19476	*100.0*	1741	*100.0*	11
Unknown, n/a	9055		1366		

Significant differences in activity at the time of becoming a casualty are apparent for injuries and fatalities, as seen in Table 11. More of the injured (38% vs 5% for fatalities) are involved in proactive behaviour such as fire fighting or rescuing others. Being asleep or unable to act is more prevalent among fatalities (58% vs 28% for injured). Similar proportions are listed as escaping at the time of injury but it is likely that they were subject to fire products before this time.

Table 11: Activity at time of injury (% of all injuries/fatalities in italics).

	Injuries	*%*	Fatalities	*%*	*I/F* ratio
Fire control	5304	*28.8*	39	*2.3*	136
Escaping	5151	*28.0*	511	*30.2*	10
Sleeping	4190	*22.7*	756	*44.6*	6
Attempting rescue	1619	*8.8*	44	*2.6*	37
Unable to act	1056	*5.7*	245	*14.5*	4
Irrational action	919	*5.0*	88	*5.2*	10
Other	188	*1.0*	10	*0.6*	19
Total known	18427	*100.0*	1693	*100.0*	11
Unknown, n/a	10104		1414		7

It can be surmised that the fatalities were more likely to be sleeping and the injured more likely to be engaged in fire control or rescue when they first were subject to smoke or thermal injury. A comparison of those who undertook fire control shows that the *I/F* ratio changes from 503 (awake) to 130 (asleep), perhaps indicating the importance of early discovery.

Fire location

A final feature related to occupant behaviour that produces differences in types of casualty is the location of the fire. Table 12 lists fires in apartment buildings by area of origin. It distinguishes bedroom, lounge and kitchen fires and combines all other locations as one category. This 'other' category includes fires that start outside apartments, for example in foyers and corridors, but also contains an unknown proportion which may be within apartments or in common areas in a building eg. laundries and internal stairwells. Table 12 includes the number of fires, to put the casualties in perspective. The accompanying Figure 2 is based on data in Table 12 and gives the rates of injury and fatality per 1000 fires.

Table 12: Casualties by location of fire.

	Fires	Injuries	*%*	Fatalities	*%*	*I/F* ratio
Kitchen	174831	9018	*31.5*	376	*12.1*	24
Bedroom	62440	7701	*26.9*	959	*30.8*	8
Lounge	35865	5349	*18.7*	1002	*32.2*	5
Other	147179	6567	*22.9*	774	*24.9*	9
Total	420315	28635	*100.0*	3111	*100.0*	9

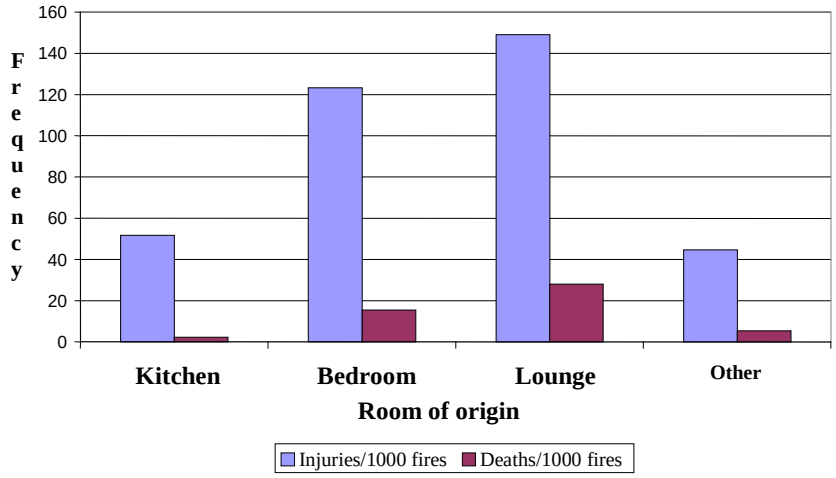

Figure 2: Casualties per 1000 fires by location of fire.

As has been shown earlier, kitchen fires are significantly more likely to lead to injuries than deaths (and, indeed, have the lowest rate of either casualty per 1000 fires). Considering their frequency (almost three times the number of bedroom fires and five times the number of lounge room fires), both injury and fatality occur less frequently than in bedroom and lounge room fires. This is in spite of the fact that around a quarter of kitchen fires spread beyond the kitchen and only 6% of bedroom fires do so. Like kitchen fires, about a quarter of lounge fires and those in the 'other' category spread beyond the room of origin.

Figure 2 shows that of the four areas, lounge room fires produce the highest casualty rate per 1000 fires for both injury and fatality.

Safety features, injury and fatality

Earlier findings[4] on the association between building safety features, injuries and fatalities, are summarised here because understanding the behaviour and characteristics of casualties illuminates them. Both injury and fatality rates per 1000 fires are lowest when sprinklers are present (respectively 49.6 and 2.7). In non-sprinklered buildings, the rates are higher and vary with the presence of detectors and protected construction as seen in Table 13, but not by as much as might be expected. Socio-economic and other factors that determine who lives in these buildings also relate to the propensity for starting accidental fires and to the probability of casualty, so it is not the presence of these safety features alone that contributes to outcome.

The presence of detectors appears to be associated with a small reduction in the number of fatalities but an increase in injuries, indicating perhaps that some people are warned in time to fight the fire or take protective action.

Table 13: Casualties by presence of detectors and protected construction (no sprinklers).

Detectors	Protected construction	Injuries per 1000 fires	Fatalities per 1000 fires	*I/F* ratio
Yes	No	86.8	8.7	7
Yes	Yes	84.1	6.8	10
No	Yes	71.9	7.5	10
No	No	65.5	9.4	12

Outcomes relating to sprinklers, detectors or protected construction reflect the *response* of people in a given fire. However, just as the initial accidental involvement with ignition or pyrogeny is significant in fatality[3], the same may be true for injuries. Thus, the importance of discovering the similarities and differences leading to severity of casualty should not be underestimated.

SUMMARY AND DISCUSSION

The NFIRS data indicate some important differences between fatalities and injuries. Most injuries occur in fires with no fatalities but about 4 in 10 fatal fires also have injuries.

Exposure to fire products and primarily to smoke is the primary feature of both types of casualty but burns are more often cited for injury than for fatality. Gender differences for fatality, where males in all age groups under 70 years considerably outnumber females, are less noticeable for injury. However, men are more likely to become fatalities than women for adults of any age when the parent populations are taken into account. The presence of sprinklers reduces both injury and fatality rates per 1000 fires but, in a comparison with non-sprinklered buildings, the rate of injury is less affected than the rate of fatality. Having detectors and/or protected construction leads to marginal differences in outcome.

There are two ways to view the findings. Firstly, there are changes in proportions within the injury or fatality category and secondly, changes in the ratio of injury to fatality. A summary follows of the most evident factors associated with casualty differences. It is obvious that the factors interrelate in different ways and to different degrees.

1. Large proportion of injuries:

    being very old (70+) or very young (<4 years)

    being in the 15-39 year age group

    being in the 20-39 year age group

    kitchen fires and bedroom fires

    smoke inhalation

    being awake and unimpaired at ignition

2. Large proportion of fatalities:

    being very old or very young

    being asleep at ignition

    being incapacitated at ignition

    night time fires

    smoke and burns (NFIRS data)

    smoking-related fires

    bedroom and lounge fires

3. Large number of injuries compared with fatalities:

    being awake and unimpaired at ignition

receiving burns only

fire control

rescue

contact with objects affected by fire

falling or stepping on

kitchen fires

unattended

being off property at the time of ignition

4. Large number of fatalities compared with injuries:

being caught or trapped by the fire

receiving smoke and burn injuries

being bedridden, too young or old to act, or drug impaired

It has been shown that many of those killed in fires have been engaged directly or indirectly with the fire start, often as part of normal activity, and a proportion have had minor (sometimes major) experience of a fire[3]. It is likely that others who have fires are in similar circumstances but the evidence is not available to state whether injury results primarily from misjudgement after discovery or from involvement with the fire from the start. The fact that most of the injured are awake and unimpaired at ignition suggests that what is being seen is one end of an effective response spectrum that is different from fatalities.

Although the rate of injury is high with attempts at controlling fires or rescuing, it is inappropriate to suggest that occupants avoid these actions. Occupants succeed in extinguishing most residential fires (various estimates suggest that there are 8 to 10 fires for every fire that results in a fire brigade callout) and in rescuing others - fire-fighting and rescue attempts are not major causes of fatality. Clearly, when people are called on to engage in such activities, they continuously assess the situation and mostly respond adequately even if the event is unpredicted and a response has never been considered beforehand. However, there may be particular sub-groups that are more likely to misjudge the degree of danger and/or their ability to cope.

As well as the direct relationship between casualties and fire ignition, there is another issue that needs further investigation - the role of intoxication and/or long-term effects of alcoholism in injury. While coroners' records give undeniable importance to the role of alcohol among fatalities, NFIRS statistics underestimate it. It is quite probable that the role of alcohol in injuries and even in having a fire in the first place is underplayed. Accident statistics in general indicate its importance and especially so among younger adults.

CONCLUSIONS

Different factors are involved in injury and fatality outcomes in apartment fires and they relate directly to characteristics and behaviour of occupants. It is not appropriate to treat injuries and fatalities as though they are on one continuum from non-injury through injury to fatality. Non-injury and injury outcomes from fire may be on the same spectrum, (there is no evidence either way), but factors contributing to fatalities are sufficiently different from injuries to indicate that caution is needed in trying to predict injury as against fatality from fires. This may involve re-consideration of occupant groups, scenarios and occupant behaviour in models.

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