Fire Research Report

Unintentional Fire-Related Childhood Injuries in Auckland Resulting in Hospitalisation or Death 1989-1998

BRIDGET KOOL

June 2001

The aim of this report is to provide a brief summary of the literature relating to fire injury among children in developed countries, and to give an overview of unintentional fire-related injury resulting in death or hospitalisation among children aged 0 -14 years in the Auckland region from 1989 to 1998.

A systematic review of the published literature was carried out to address questions relating to fire-related childhood injury. A retrospective population-based descriptive study was undertaken to investigate the epidemiology of unintentional fire-related hospitalisations and deaths among Auckland children (0 – 14 years) from 1989-1998. The study population was children aged 0 – 14 years who died or had a primary admission to Starship or Middlemore hospital during the study period for a fire-related injury occurring in the Auckland region. The exposures of interest included basic demographics, the circumstances surrounding injury, and outcomes of injury.

The home environment (including yard, outbuildings, and driveway) was the most common place of fire-related injury resulting in death (95 percent) and hospitalisation (93 percent). House fires were responsible for 79 percent of fire deaths and eight percent of hospitalisations. Fires in parked cars accounted for 21 percent of fire deaths, and three percent of hospitalisations. House fire deaths were the leading cause of child fire fatalities in this study, consistent with and international study findings. New Zealand.

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Unintentional fire-related childhood injuries in Auckland resulting in hospitalisation or death 1989 – 1998

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A report for the New Zealand Fire Service Commission

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INTRODUCTION

This report to the New Zealand Fire Service Commission describes features of fire-related incidents in Auckland New Zealand that resulted in the death or hospitalisation of children aged 0 to 14 years during the years 1989-1998. The report is in two parts the first part focuses on a systematic review of the current literature regarding fire-related injury in children. The second part of the report describes the findings of a descriptive study of children who were hospitalised or died as result of unintentional fire-related injury during the study period.

This report is one of a series contracted for the New Zealand Fire Service Commission Contestable Research Fund for the 2000 – 2001 research year.

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Aim

The aim of this report is to provide a brief summary of the literature relating to fire injury among children in developed countries, and to give an overview of unintentional fire-related injury resulting in death or hospitalisation among children aged 0 -14 years in the Auckland region from 1989 to 1998.

Study design and methods

A systematic review of the published literature was carried out to address the following questions relating to fire-related childhood injury: 1) *What is the extent of the problem?* 2) *Who sustains the injuries, and how and when do they occur?* 3) *What risk factors are associated with this type of injury?* 4) *How can fire-related childhood injury be prevented?*

A retrospective population-based descriptive study was undertaken to investigate the epidemiology of unintentional fire-related hospitalisations and deaths among Auckland children (0 – 14 years) from 1989-1998.

The study population was children aged 0 – 14 years who died or had a primary admission to Starship or Middlemore hospital during the study period for a fire-related injury occurring in the Auckland region. The exposures of interest included basic demographics, the circumstances surrounding injury, and outcomes of injury.

Information was obtained through the systematic review of relevant documentation. The number of children resident in the Auckland region at the 1991 and 1996 Census surveys served as the denominator for rates of injury. Results of the study are presented for two distinct groups: fire-related injury resulting in death, and fire-related injury resulting in hospitalisation.

Results

Nineteen fatalities and 148 hospitalisations were identified during the study period. The age-specific average annualised rate for fatal cases was 0.8 per 100,000, and 6.4 per 100,000 for hospitalisation cases. The mean age of fatal cases was 3.5 years, and 6.9 years for hospitalisations. Younger children were at greatest risk of dying from fire-related injury, and had the highest rates of hospitalisation in the study. Males were more likely to die and be hospitalised as a result of fire-related injury than females. The highest rate of hospitalisation for males was observed in the 10-14 year age group, in females the rate was highest in the 0 – 4 year age group. Pacific Islands children were most at risk from fire-related death, whilst Maori children were most likely to be hospitalised. Socioeconomically disadvantaged children appeared to be at increased risk of fire-related hospitalisation and death.

The home environment (including yard, outbuildings, and driveway) was the most common place of fire-related injury resulting in death (95 percent) and hospitalisation (93 percent). House fires were responsible for 79 percent of fire deaths and eight percent of hospitalisations. Fires in parked cars accounted for 21 percent of fire deaths,

and three percent of hospitalisations. Ignition of highly flammable material (ICD E code E893) and ignition of clothing (ICD E code E894) were the leading cause of injury requiring hospitalisation, accounting for 34 percent and 30 percent of admission respectively. Playing with matches or lighters was the most common source of ignition for deaths and hospitalisations. Fatal fires involving young children (0 – 4 years) occurred most often during daytime (8:00 a.m. – 7:59 p.m.) and in the older age group (5 – 9 years) during the night time. In contrast fire-related injury requiring hospitalisation for all age groups peaked between 4:00 p.m.- 7:59 p.m.

Ninety percent of fire fatalities died at the scene, the remainder died in hospital. Among fatal cases in which the Total Body Surface Area (TBSA) of the burn was recorded, all had a TBSA burn of 65%.

Conclusion

In Auckland children aged less than five years, males, ethnic minorities, and the socially disadvantaged appear to be at increased risk of fire-related death or hospitalisation. These finding are consistent with previous research in New Zealand and overseas. There was an apparent excess risk of fire-related death among Pacific Islands children, and an excess risk of hospitalisation among Maori children. Increased risks among these groups may reflect in part, their over representation in the proportion of people living in disadvantaged circumstances. House fire deaths were the leading cause of child fire fatalities in this study, consistent with New Zealand and international study findings.

The fatalities as a result of fires in parked cars in this study are of concern, as this mechanism of injury was not featured in the international literature reviewed. Despite dramatic reductions in fire-related injury due to the ignition of clothing since the introduction of flame retardant nightwear, ignition of clothing in general was a leading cause of injury in this study. While relatively few house fires in this study were related to careless disposal of smoking material, there was a high proportion of both fatal and non-fatal cases resulting from children playing with matches or lighters.

Childhood fire-related injury is a significant cause of childhood mortality and morbidity in New Zealand. The findings from this descriptive study have provided some insights into the epidemiology of fire-related childhood injury. The findings indicate the need for analytical research to assist the development and implementation of interventions to reduce the mortality and morbidity associated with unintentional fire-related injury among children.

2 RECOMMENDATIONS

1) The New Zealand Fire Service Commission develops where appropriate fire prevention initiatives in partnership with Maori ensuring the principles of the Treaty of Waitangi are adhered to. This process will be aided by the establishment of Maori liaison staff within the New Zealand Fire Service to help develop and evaluate fire prevention initiatives relevant for Maori.

2) The New Zealand Fire Service Commission develops where appropriate, fire prevention initiatives in partnership with Pacific Islands groups. This process will be aided by the establishment of Pacific Island liaison staff within the New Zealand Fire Service to help develop and evaluate fire prevention initiatives relevant to Pacific Island communities.

3) The New Zealand Fire Service Commission ensures that findings of this research are disseminated among agencies and individuals concerned with the well-being of New Zealand children.

4) The New Zealand Fire Service Commission liases with those agencies and individuals to incorporate fire safety strategies into individual and population based health promotion strategies for children. Relevant agencies and authorities include: Plunket, Safekids, early childhood education providers, the Commissioner for Children, the Ministry of Youth Affairs, the Ministry of Education, Te Puni Kokiri, the Ministry of Pacific Island Affairs, Maori and mainstream health service providers including Public Health service providers, and Maori and mainstream social service providers.

5) The New Zealand Fire Service Commission continues to resource effective initiatives to educate service providers, caregivers, and children regarding the dangers of children having access to, and playing with matches and lighters.

6) The New Zealand Fire Service Commission includes in fire safety educational material targeted at children and their families, advice regarding the inappropriateness of cars as play areas for children, and recommending the locking of parked cars in domestic properties.

7) The New Zealand Fire Service Commission supports the development of effective prevention strategies to address petrol-related injuries among adolescents including the safe storage of petrol for domestic use.

8) The New Zealand Fire Service Commission liases with the Ministry of Consumer Affairs regarding the possibility of flammability standards for children's clothing in line with those in existence for sleepwear.

9) The New Zealand Fire Service together with the Insurance Council of New Zealand explores the feasibility of premium lowering incentives for clients with hard-wired smoke detectors, and domestic sprinkler systems in place.

10) The New Zealand Fire Service Commission supports mandatory installation of hard-wired smoke alarms in new dwellings, and investigates the feasibility of legislation to ensure landlords have smoke detectors in place in residential rental properties.

11) The New Zealand Fire Service Commission investigates the applicability of retrofitting sprinkler systems in dwellings managed by Housing New Zealand Limited.

12) The New Zealand Fire Service Commission investigates opportunities to reduce the costs associated with installation of fire prevention technology.

13) The New Zealand Fire Service Commission is involved in any future consultative process to establish a national coronial system in New Zealand.

14) The New Zealand Fire Service Commission improves the consistency and quality of Fire Service data collected to improve the accuracy and usefulness of the data for injury prevention purposes. Specifically mandating the recording of the following: personal details of victims injured or killed in a fire eg. name, age, gender, street address; absence/presence of fire safety technology eg. smoke alarms, sprinkler systems; and absence/presence of smoking materials.

15) The New Zealand Fire Service Commission establishes an ongoing analysis system of fire incidents resulting in injury or death, combining routinely collected fire service data with population data, incorporating modern epidemiological tools including GIS mapping.

16) The New Zealand Fire Service Commission gives consideration to future research into fire-related injury among children. Two studies proposed are:

    i) A case-control study to identify potentially modifiable risk factors for fire-related childhood injury

    ii) A study to evaluate the short and long term effects of non-fatal fire-related childhood injury, and the interventions designed to reduce the impact of these injuries.

3 BACKGROUND

3.1 Overview

Fires account for one percent of the global burden of disease [1]. Domestic fires are the leading cause of thermal injury death in New Zealand children [2]. Fire/flame-related burns have been cited as responsible for between 10 and 39 percent of paediatric burn admissions to hospital [3-10].

Numerous studies have described the epidemiology of fatal and nonfatal childhood burn injury of all types - scalds, contact, chemical, and flame [2-18]. But few studies have examined the epidemiology of injuries in children as a consequence of exposure to fire, flames, and smoke [19-21].

In July 1999 the New Zealand Fire Service Commission developed a Statement of Strategic Direction [22]. One of the four key strategic directions focuses on *resource re-allocation and value-for-money expenditure*, integral to this is the theme of *science-driven decision-making*. This study assists the Strategic Direction Plan by: 1) providing demographic details of the nature and type of fire incidents resulting in hospitalisation or death, and 2) describing demographic characteristics of children injured as a result of fire in the Auckland region during a 10-year period.

For the purpose of this report, the term fire or flame burn will relate to the following definition:

> *Flame burn:damage to tissue caused by thermal energy inherent in flames or by the by-products of combustion (includes smoke inhalation and burns from radiant heat of flames which do not come in contact with skin) (Christoffel, 1992,p.1032)*[23]

3.2 Objectives

The objectives of this report are:

1) To systematically review and summarise the literature on fire-related childhood injury in developed countries.

2) To investigate the nature, type, severity, and determinants of fire-related injury among Auckland children.

3) To determine if there are priority areas specific to certain age, sex, ethnicity, and socioeconomic subgroups with respect to fire-related injury prevention.

4 LITERATURE REVIEW

Despite advancements in the management of major burn injuries and associated decrease in mortality fire-related injury remains a significant cause of childhood injury morbidity and mortality both internationally and in New Zealand [24-27]. Flame-related injuries may result in unsightly scars, long-term physical and psychological effects, the loss of productive years, and in severe instance death [2, 28-30].

The following section summarises findings of a review of the literature addressing the following questions: 1) *What is the extent of the fire-related childhood injury problem?* 2) *Who sustains fire-related childhood injury, and how and when does it occur?* 3) *What risk factors are associated with fire-related childhood injury?* 4) *How can fire-related childhood injury be prevented?* in developed countries.

4.1 What is the extent of the fire-related childhood injury problem?

4.1.1 International mortality and morbidity

In 1998 for high-income countries for both sexes in the 5 – 14 year age group, fires were the ninth leading cause of all deaths, and in the 0 – 4-year age group the 12th leading cause of all deaths. In low and middle-income countries in 1998, fires were the 11th leading cause of all deaths in the 5 – 14 year age group [31].

Fire-related injury is the third leading cause of injury and death among American children (0-14 years) [6, 20, 29]. In 1994 fire accounted for 17 percent of all injury deaths in children aged less than five years in America, and claimed 3.75 lives per 100 000 child years [32]. Fires are the second leading cause of unintentional injury death in children aged 1 - 14 years in the United Kingdom (UK) [33, 34].

In New South Wales, Australia, for the period 1985-1987 fire/flame was the fourth leading cause of injury-related mortality in the 0 -14 year age group. In the 0 – 4 year age group fire/flame was the third leading cause of injury-related death. By age 10 - 14 years the mortality rate from fire/flame had decreased and was ranked ninth [35].

Studies in developed countries have demonstrated fire to be responsible for between 71 and 93 percent of all burn-related deaths among paediatric burn admissions [6, 7, 9, 10]. It should be noted that the majority (82 percent) [20, 21] of child fire fatalities die at the scene, thus resulting in an under representation of the severity of injury picture if hospitalisation data only is examined.

Mercier in a study of 937 paediatric burn admissions reported victims of fire/flame burns were eight times more likely to die, than victims of other types of burns [10]. In Canada, Ryan *et al.* deduced that for every hospital child fire-related death there were at least five who died either at or enroute from the scene [9]. The high fatality rate among young children and the elderly injured in house fires has been attributed to their difficulty in escaping from burning environments, and their poor survival outcome [36-39].

There has been an international decline in deaths due to fire-related injuries in the past decade. In a study of childhood injury fatality rates in 15 European Union member countries, for the period 1984-93 the decline in fire-related deaths ranged from eight percent in Spain, to 77 percent in Finland [40]. Similarly in Victoria, Australia between 1970 and 1994 burn rate mortality decreased by 50 percent [7]. In the United States a 33 percent reduction in age adjusted rates of fire and burn mortality was observed across all age groups between 1985 and 1995 [40]. Despite fire-related fatality rates decreasing a disproportionate number of children are injured or killed [21, 41].

Fire-related injury is cited as responsible for 12 to 39 percent of hospital burn admissions [4, 9, 10, 13, 18]. In France burns account for between three and eight percent of childhood injury with one study of 937 patients showing flame burns responsible for 17 percent of burn admissions [10]. El-Badawy *et al*, in a prospective study of 350 children admitted to an Egyptian burn unit, found 39 percent of admissions were due to flame burns [4]. In Canada fire is the second most common cause of burn injuries in children, and in a study of 583 paediatric burn admissions fire was responsible for 24 percent of admissions [9]. Finland and Iceland have relatively low rates of paediatric hospital burn admissions due to fire/flame (less than 10 percent, and 12 percent respectively) [13, 18].

In New South Wales, Australia, for the period 1985-1987, fire/flame was the 10th leading external cause of injury-related hospitalisation in the 0 – 1-year age group [35].

A Scottish study of 1114 paediatric inpatients demonstrated a dramatic decline in the number of flame burns admitted, from 14 percent of total admissions in 1965 to only two percent of total admissions during 1988-1990 [11]. In Australia, Streeton and Nolan in a study of 4992 admissions to a children's burns unit between 1970 and 1994, noted a 57 percent reduction in flame burn admissions during the study period [7]. The decline in hospital admissions from fire/flame-related injury in these two studies was attributed to the effectiveness of legislation relating to building regulations and smoke detectors; Acts controlling the quality of material used for clothing, toys, and furniture; a move away from open flame heating systems; and improvement in the electrical wiring of houses [7, 11].

4.1.2 New Zealand mortality and morbidity

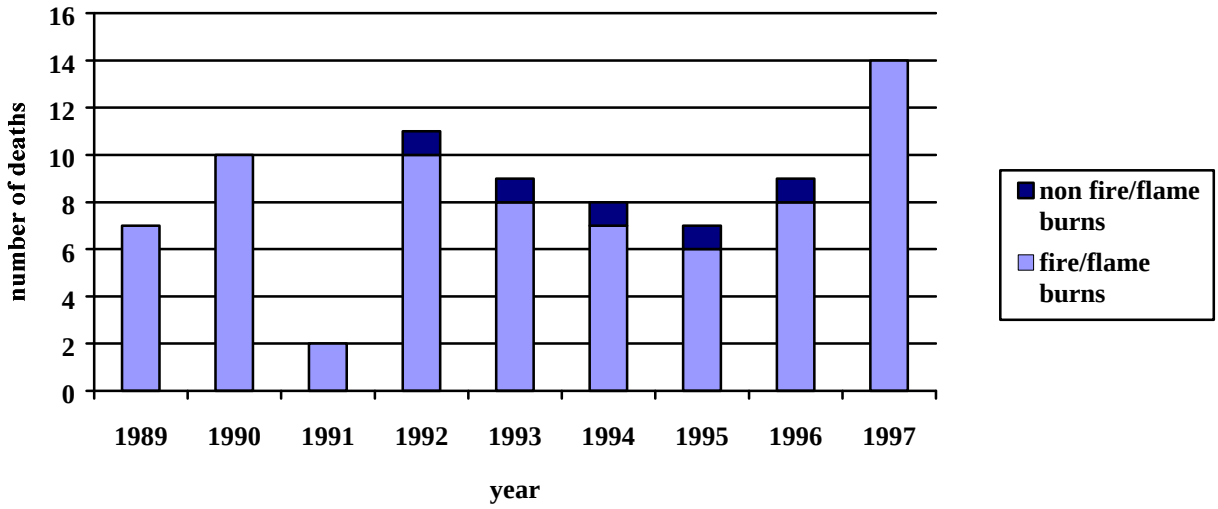
During the nine-year period 1989 to1997, fire/flame accounted for 94 percent of all unintentional burn deaths among New Zealand children (Figure 1. See following page) [42]. This figure is consistent with the high mortality from fire /flame injury compared with other burns injuries reported in international studies [6, 7, 9, 10].

During the period 1989 to 1997, deaths as a result of fire/flame injury accounted for eight percent of all unintentional injury deaths among New Zealand children [42]. Maori have been identified as a high-risk group for fire deaths in New Zealand [43]. For the period 1985 to 1994 fire/burns were responsible for seven percent of Maori infants

(children aged less than 1 year) deaths, and 15 percent of Maori children aged 1 to 14 years deaths in New Zealand [44].

Figure 1. Unintentional burn deaths among New Zealand children (0-14 years).1989-1997

Source: National Injury Inquiry Service. Injury Prevention Research Unit, Otago University



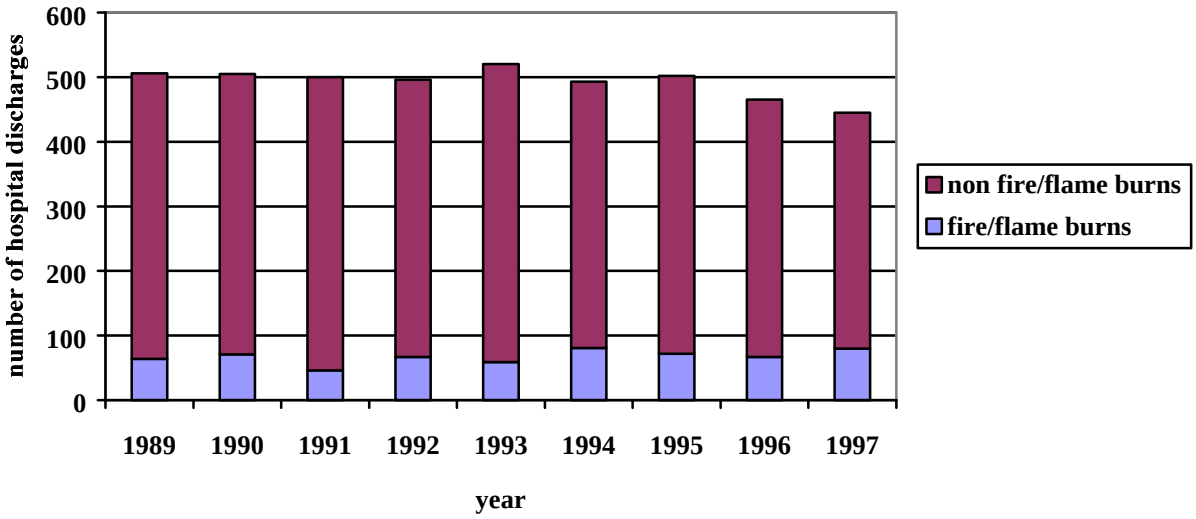
Compared with the USA New Zealand has half the rate of fire-related deaths among children aged 0 – 14 years, Langley and Smeijers suggest this may be attributable to a higher proportion of American housing environments being multistoried and constructed of material of higher flammability [45]. In New Zealand in the 10 years from 1986 to 1995, fire-related injuries were the fourth leading cause of injury death in children aged 0 -14 years [46].

The principal cause of thermal injury-related death among New Zealand children is house fire incidents [2]. Annually in New Zealand there are approximately 6000 domestic fires resulting in around 23 deaths (all ages) per year [47]. The Auckland region has on average 28 percent of New Zealand's child population (1991 census 27.3%, 1996 census 29.4%) [48]. In Auckland during 1995 and 1996, four children died from burns received in domestic fires [49].

In 1996, 119 children were hospitalised in New Zealand as a result of accidents caused by fire/flame [50]. Figure 2 (see following page) displays the numbers of children discharged from hospital as a result of unintentional burn injury in New Zealand during the period 1989 to 1997. During this period unintentional fire/flame burns accounted for 14 percent of all hospital discharges in this group [42]. During the period 1985 to 1994 fire/burns were responsible for 20 percent of all injuries to Maori infants (<1 years), and eight percent of all injuries to Maori children aged 1 to14 years[44].

Figure 2. Unintentional burn-related hospital discharges among New Zealand children (0-14 years).1989-1997

Source: National Injury Inquiry Service. Injury Prevention Research Unit, Otago University



Excludes:

-those discharges as a result of readmission for an existing injury
-discharges for a hospital *length of stay* < 24 hours
-discharges where there was not a primary diagnosis of injury cases of patients who died in hospital

As is clearly displayed in Figures 1 and 2, unintentional fire related injury accounts for a minority of unintentional hospital discharges but the majority of unintentional burn deaths among New Zealand children.

4.1.3 Cost of injury and quality of life measures

The annual societal cost of childhood fire/burn deaths in America has been estimated in a "cost of burn injury" model as being between $2.9 and $4.4 billion (US), and for nonfatal burns, $3.5 billion (US) [20, 29].

Injuries to children may also result in a reduction in the quality of life for the child and their family. Children who are disabled by injury may suffer permanent cognitive or motor functional loss, or experience lifelong discomfort and pain. Children who sustain burn injuries may experience both acute and chronic effects on psychological adjustment, appearance and function [30].

Herndon *et al.* in a long-term outcome study followed-up 12 children with greater than 80% Total Body Surface Area (TBSA) of burn for a four-year period. Eleven out of the twelve subjects had sustained flame injuries. The results indicated 50 percent of children old enough to be evaluated were completely independent in activities of daily living. However 33 percent of children had regression, excessive fear, neurotic, and somatic complaints [25]. A major limitation of the study was the short follow-up period. It is important to know the duration of these sequelae, in order that the true burden of disease for burn injury can be quantified.

In 1992 the World Health Organisation (WHO) conducted the Global Burden of Disease study with the specific aim of measuring the burden of injury and disease on the world [51]. Disability-Adjusted Life Years (DALYs) were developed as the measurement unit for this study. DALYs combine the number of years of life lost from premature death with the loss of health from disability (one DALY equates to one lost year of healthy living) [31]. In the world in 1990 for all causes of DALYs, fires ranked 27th out of 96 disease or injuries, ahead of HIV, diabetes mellitus and asthma [51].

It is difficult to measure the burden of injury on society, but establishing the economic and non-economic costs of injury has many benefits: 1) aids decision-making regarding appropriate funding of research and prevention initiatives; 2) provides baseline information for establishing cost-benefits of intervention strategies; and 3) provides another dimension to highlighting the significance of injury beyond standard epidemiological measures of death and hospitalisation [52, 53].

In New Zealand the hospitalisation costs alone for treating children with burn and scald injury have been estimated at $3 million per year [54]. In 1988 thermal injury to children resulted in a total of 6386 days of hospital stay in New Zealand [2]. Lofts in a 1989 study of 26 patients admitted to Middlemore Hospital undertook a retrospective review of records in an attempt to estimate the total cost of inpatient management of major burns. He estimated an average cost of $647 per patient per day, or $927 per percentage of burn injury (1991 values) [55]. No published New Zealand studies were identified that had estimated that societal cost of childhood fire/burn injury.

In addition to health-care related costs, are costs relating to property damage from house fires. In New Zealand during the period winter 1998 to winter 1999, there were a total of 9,066 insurance claims for property damage as a result of domestic fire. The total cost of this damage was $45,474,597.20 (Personal communication. Neil Gravestock, Manager, Fire Engineering Department, Insurance Council of New Zealand).

4.1.4 Associated injury

Injuries associated with fire-related accidents include skin burns, airway burns, smoke inhalation, and carbon monoxide poisoning. Mercier and Blond in a study of 937 paediatric burns hospital admissions, found flame injuries in this group were both extensive (mean surface area burned, 17.5%) and deep. Ninety-nine percent of cases required grafting [10].

Parker *et al.,* in a study of fire fatalities among New Mexico children, found 82 percent of victims died at the scene. Seventy-five percent of the study cases died from smoke inhalation or carbon monoxide poisoning, 18 percent from thermal injury, and five percent from mixed thermal and smoke inhalation [20].

An American study of 449 paediatric burn cases reported flame burns associated with smoke inhalation injury were on average three times larger than that of flame burns without smoke inhalation injury (35.6% ±3.5% *v* 12.1%±0.5%; P <.001). The incidence of smoke inhalation injury in young children with flame burns was higher than that seen in older children with flame burns (50% v 22.7%; P <.001). Using logistic regression

analysis, the authors validated inhalation injury as an independent predictor of mortality [6].

Despite advances in the reduction of mortality related to thermal injuries, mortality from fire-related burns remains high when a major body surface area burn is complicated with smoke inhalation [27].

4.2 Who sustains fire-related childhood injury, and how and when does it happen?

Internationally and in New Zealand the risk of dying from fire-related injury in children diminishes with age, with young children most at risk [6, 10, 20, 29, 56-58]. The majority of child fire-related deaths occur in the home [20, 21], most are the result of house fires [36]. Thirty-three to 66 percent of house fires involving children under-five years of age are started by children playing with matches [21, 29, 59], a large portion of these originating in sleeping areas [57]. Fire deaths are most likely to occur during the weekends [37, 39, 60] in either late evening or early morning [21, 39, 56, 60]. Fire deaths are reported as more likely to occur in winter months than summer [36, 37, 39, 61].

Boys are more likely to be killed or injured as a result of fire-related injury than girls are [4, 6, 7, 9, 10, 12, 17, 18, 55]. Ethnic minorities are over represented in both fatality and hospitalisation rates for fire-related injury [39, 57, 62-64].

Rates of fire-related injury resulting in hospitalisation are considerably lower than rates for scalds, but fire-related injury is usually of a more extensive and severe nature than scald injuries [10, 65].

The use of flammable liquids by adolescents specifically petrol, is attributed to a high proportion of fire-related hospitalisations in this age group [7, 10, 20, 66-68].

The mechanism of injury for fire-related injuries in developing countries differs from that in developed countries and primarily relates to the traditional utilisation of either wood burning, or kerosene stoves for cooking and heating [4, 5, 69]. Fire-related injury as a result of abuse or suspected abuse is uncommon in developed countries [20, 70].

There was a paucity of data relating to time of day, day of week, and seasonality of fire-related hospitalisations in the published literature reviewed.

4.3 What risk factors are associated with fire-related childhood injury?

Absence of a functioning smoke detector/alarm is considered one of the most important modifiable risk factors for fatal fire death in all age groups [36, 56, 60]. Maintenance of alarm function is an important risk factor in determining the effectiveness of this intervention.

The presence of cigarette smokers in households is a major causal factor for domestic fires [32, 36, 56, 60, 64], and is cited in America as the leading cause of fatal fire injury and the second leading cause of non-fatal fire injury for all ages [64].

Clothing (both in terms of style and type of material) has been noted to be a significant risk factor for fire-related injury for children [21, 37]. Despite a significant decline in clothing ignition-related hospitalisations over the past decade, ignition of clothing remains a significant cause of burn injury morbidity [7, 36].

Numerous studies have specifically examined maternal characteristics associated with fire/burn injury in young children [17, 32, 71]. A study of maternal risk factors associated with child fire deaths, found that low education status, more than two other children, and mothers aged less than 20 years, were significantly associated with higher child fire fatality rates [32]. Childhood injury rates in general are higher for children of lone mothers [33]. Maternal characteristics although difficult to modify, are significant factors to be acknowledged when planning and developing fire injury prevention strategies targeted at young children.

There is a strong association with low socioeconomic status and fatal fire injury among children [23, 72, 73]. The main factors associated with low socioeconomic status and risk of fire-related injury are high rates of lone parenthood, poor housing conditions, high smoking rates, and low rates of smoke alarm ownership.

4.4 How can fire-related childhood injury be prevented?

In general injury terms, successful prevention initiatives are those that use an interdisciplinary approach and focus efforts at an individual, community and national level [74, 75]. Interventions can be broadly viewed as educational, environmental, and legislative/regulatory. These three approaches will be summarised from a child fire-related injury perspective.

Educational injury prevention interventions targeting fire-related injury among children have experienced varying levels of success and few have demonstrated an associated decrease in injury rates [76-81]. A systematic review of community-based education programmes encouraging the use of smoke alarms, combined with smoke alarm giveaways, was unable to support a positive effect on either smoke alarm ownership or burn incidence [78]. Some population-based education programmes have been successful combining media campaigns with fire brigade visits, although these interventions are costly [81]. In general fire safety injury prevention education interventions have in the past, suffered from lack of rigorous evaluation. In the future, fire safety education interventions for children would benefit from the use of analytical studies to evaluate their efficacy.

Environmental fire injury prevention interventions have been successful in reducing fire-related injury rates. A good example of this has been the introduction of flame-retardant sleepwear, which has resulted in a substantial decrease in deaths as a result of clothing ignition [2, 7, 36, 82]. Another example is automatic sprinkler systems that are

extremely effective in extinguishing a developing fire, although as yet there is little published research available [81].

For the most part legislation and regulation are required to support environmental injury prevention interventions. Examples of legislation in place to support fire safety are the mandating of smoke alarm installation in new homes or in homes having modifications, and regulations controlling the fire retardant nature of materials used in the construction of furniture. In reality the benefits of legislation and regulation seldom reach those who are socially disadvantaged. For example in relation to fire-related injury, low-income families are less likely to be building new homes or buying new furniture. A major limitation of legislative and regulatory interventions is the lack of enforcement [83].

Prevention activities are described as *passive* or *active* in nature. *Active* actions require an individual/s "to go and do something", that is to change or alter behaviour, for example keeping smoking materials out of reach of children. In contrast, *passive* activities require no direct action by the individual/s, for example the introduction of sprinkler systems in state rental properties. Research has demonstrated *passive* interventions are more successful than *active.* This is attributed to the weak link between changes in knowledge and attitudes, and changes in behaviour [81, 82].

Successful injury prevention initiatives employ a combination of environmental/product change, educational, and legislative interventions and use both *passive* and *active* approaches [82]. An example of this process in action is described by Onwuachi-Saunders *et al* [84]. They describe the establishment of a Youth Fatality Review Team. The team reviews all children and youth (<21 years of age) deaths. Utilising a community-based approach they generate science-based information and convert it into action. The process uses multiagency case analysis, to determine enabling factors and barriers for child and youth fatalities. The development and implementation of injury prevention interventions is fostered through the making of recommendations for educational and policy change [84].

4.5 Chapter Summary

The literature review provided an overview of demographic characteristics, risk factors associated with, and prevention strategies for, fire-related childhood injury.

Demographics

- The risk of dying from fire-related injury diminishes with age, with young children most at risk.
- Boys are more likely to be killed or injured as a result of fire-related injury than girls.
- Ethnic minorities are over represented in both fatality and hospitalisation rates for fire-related injury.
- The majority of fire-related deaths occur in the home. House fires are by far the major cause of fire-related fatalities among children. House fires involving children under-five years of age are primarily started by children playing with matches a large portion of these originating in sleeping areas.
- Fire deaths are most likely to occur during the weekends in either late evening or early morning. And are more likely to occur in winter months than summer.

- Rates of fire-related childhood injury resulting in hospitalisation are considerably lower than rates for scalds, but fire-related injury is usually more extensive and severe than scald injuries.
- The use of flammable liquids by adolescents specifically petrol, is attributed to a high proportion of fire-related hospitalisations in this age group.
- Fire-related injury as a result of abuse or suspected abuse is uncommon in developed countries.

Risk factors

- Absence of a functioning smoke detector/alarm is considered one of the most important modifiable risk factors for fatal fire death in all age groups. Maintenance of alarm function is an important risk factor in determining the effectiveness of this intervention.
- The presence of cigarette smokers in households is a major causal factor for domestic fires, and is cited in America as the leading cause of fatal fire injury and the second leading cause of non-fatal fire injury for all ages.
- Clothing (both in terms of style and type of material) has been noted to be a significant risk factor for fire/flame injury. Despite a significant decline in clothing ignition-related hospitalisations over the past decade, ignition of clothing remains a significant cause of burn injury morbidity.
- Maternal characteristics associated with fatal fire injury in young children include low education status, more than two other children, and mothers aged less than 20 years. Childhood injury rates in general are higher for children of lone mothers. Maternal characteristics although difficult to modify, are significant factors to be acknowledged when planning and developing fire injury prevention strategies targeted at young children.
- There is a strong association with low socioeconomic status and fatal fire injury among children. The main factors associated with low socioeconomic status are high rates of lone parenthood, poor housing conditions, high smoking rates, and low rates of smoke alarm ownership.

Prevention

- In general injury terms, successful prevention initiatives are those that use an interdisciplinary approach and focus efforts at an individual, community and national level.
- Educational injury prevention interventions targeting fire-related injury among children have, experienced varying levels of success and few have demonstrated an associated decrease in injury rates. Systematic reviews of community-based education programmes encouraging the use of smoke alarms, combined with smoke alarm giveaways, have been unable to support a positive effect on either smoke alarm ownership or burn incidence. Some population-based education programmes have been successful combining media campaigns with fire brigade visits, although these interventions are very expensive. In the past fire safety injury prevention education interventions have suffered from lack of rigorous evaluation. In the future education interventions would benefit from the design of analytical studies such as randomised control trials to evaluate the efficacy of interventions.
- Environmental fire-injury prevention interventions have been successful in reducing fire-related injury rates. *Passive* interventions are more successful than *active*. A good example of this has been the introduction of flame-retardant sleepwear resulting in a substantial decrease in deaths as a result of clothing ignition. Another

example is automatic sprinkler systems that are extremely effective in extinguishing a developing fire, although as yet there is little published research available.

- Environmental injury prevention interventions require legislative and regulatory support. Examples of legislation in place to support fire safety are the mandating of smoke alarm installation in new homes or in homes having modifications, and regulations controlling the fire retardant nature of materials used in the construction of furniture. The benefits of legislation and regulation seldom reach those who are socially disadvantaged. For example in relation to fire-related injury, low-income families are less likely to be building new homes or buying new furniture. A major limitation of legislative and regulatory interventions is the lack of enforcement.

5 DESCRIPTIVE STUDY

5.1 Aim and objectives

The aim of this study was to investigate the epidemiology of unintentional fire-related hospitalisations and deaths among Auckland children for the period 1989-1998, through the systematic evaluation of available documents. Population characteristics and environmental factors associated with fire-related injury in children may form the basis for future injury prevention initiatives to reduce the incidence of fire-related injury.

The objectives for the study were:

1) To describe the personal characteristics of children in Auckland who are hospitalised or die as a result of domestic fire-related injury.

2) To describe characteristics of domestic fire-related incidents in Auckland resulting in hospitalisation or death of children.

3) To investigate if there are priority areas specific to certain age, sex, ethnicity, and socioeconomic subgroups with respect to fire-related injury prevention.

5.2 Methods

5.2.1 Study design

The study was a retrospective population-based descriptive study.

The study population was all children (0-14 years inclusive) who were hospitalised (ie. admitted and discharged) or died as a result of unintentional fire-related injury occurring in the Auckland Region during the ten year period 1st of January 1989 to the 31st December 1998.

The Auckland region was defined as the seven territorial local authorities Rodney, North Shore, Waitakere, Auckland, Manukau, Papakura, and Franklin.

Exclusion criteria for the study were subsequent admissions for a previously incurred fire-related injury that had required hospitalisation, and cases where inadequate information was provided in the inpatient record to confirm cause of injury as fire-related.

5.2.2 Case identification and data sources

Fatalities

Fatality cases were identified from coronial records, forensic pathology files held in the Forensic Pathology Department Auckland Hospital, New Zealand Fire Service (NZFS) fire incident reports, and the New Zealand Health Information Service (NZHIS) mortality dataset. NZHIS identified cases were cross-referenced with NZFS and Pathology department cases to ensure completeness of the study population.

Cases were identified from the Forensic Pathology and the NZFS using codes generic to these agencies. International Classification of Disease 9th edition (ICD-9-CM) codes (E890-899 *Accidents caused by fire and flames*) were used to identify cases from the NZHIS mortality database.

Fatality case data was abstracted from coronial records, NZFS fire incident reports, and forensic pathology files.

Hospitalisations

Middlemore and Starship Hospitals provide tertiary care to paediatric burn patients for the Auckland region. Starship hospital burn admission policy is to treat only those patients with burns less than 10% TBSA and not involving face or hands. Patients falling outside of these criteria are referred to Middlemore hospital for treatment (Personal communication. Richard Aickin.Director, Children's Emergency Department, Starship Hospital).

Hospitalisation cases were identified from Middlemore and Starship hospital casemix reports. Cross-referencing of cases identified by hospital casemix reports with NZHIS hospitalisation datasets facilitated the establishment of a complete dataset of fire-related hospitalisations, enabling identification of missed cases and resolution of cases of indeterminate cause of injury, and hospitalisation status. International Classification of Disease 9th edition (ICD-9-CM) codes (E890-899 *Accidents caused by fire and flames*) were used to identify cases from hospital casemix reports, and from the NZHIS morbidity database.

Hospitalisation case data was abstracted from inpatient records.

5.2.3 Ethnicity

Ethnicity data for Maori and Pacific Islands children has been provided wherever possible in this study. For fatality cases ethnicity was ascertained from information obtained from forensic pathology files. It is acknowledged that there has been under reporting of Maori in mortality statistics and this may result in an under-representation of Maori in this fatality data [85].

For hospitalisations ethnicity data was obtained from the child's hospital admission form. Ethnicity for the child is determined by the child's caregiver when they complete the hospital admission form on the child's admission to hospital. The use of this source of ethnicity data should have reduced the well-documented problems associated with the use of ethnicity data for Maori derived from NZHIS hospitalisation data prior to 1996 [86].

In this study when comparisons are made between Maori and non-Maori, unless stated otherwise non-Maori includes European, Asian, Pacific Islands, Indian, and other children. It is acknowledged that mortality and hospitalisation rates may also be relatively high for Pacific Islands children compared with New Zealanders of other ethnicities.

5.2.4 Analysis

Results of this study are presented for two distinct groups: fire-related injury resulting in death, and fire-related injury resulting in hospitalisation. Incidence was established for the different age and gender groups, socioeconomic status, location of the injury event, and activity being undertaken at the time of injury

5.2.5 Rates

Age-specific rates of fire-related hospitalisation and death were calculated per 100 000 population of children resident in the Auckland Region [48].

Incidents where a street address was available were geocoded to census meshblock level. A meshblock is the smallest geographical unit defined by the central government statistics agency, Statistics New Zealand. Geocoding of incidents to meshblock level facilitated allocation of a level of deprivation according to the New Zealand Deprivation index (NZDep) for each incident. NZDep is an area-based index of deprivation that combines nine variables that reflect eight dimensions of deprivation [87]. NZDep 96 was utilised for study analysis for the 10-year period.

5.2.6 Ethical considerations of the study

Ethical approval for the study was obtained from the Health Funding Authority (HFA) Ethics Committee as clinical records were used in the study. Identifying information was held separately from the study dataset and was retained as long as was required to data match. Analysis was carried out on anonymised data.

5.3 Results

5.3.1 Fire-related fatalities

It should be noted that a ruling by the Health Funding Authority Ethics Committee, in an effort to protect the identity of fatal fire victims in this study, has restricted the presentation of data to those tabulations that have three or more per cell.

5.3.1.1 Overall fatality results

During the ten-year period 1989-1998, 19 children aged 0 – 14 years died from fire-related injury in the Auckland Region, an age specific average annualised fatality rate of 0.8 per 100 000. The Auckland region's unintentional fire-related fatalities accounted for 23.6 % of national unintentional fire-related deaths among children for the period 1989 – 1997 [42]. There were no fire-related fatalities among children in the Auckland region during 1989 or 1991, and most deaths occurred in 1993 (5/19). Numbers were insufficient to examine trends in the fatality rate during the study period.

There were four fatal fire incidents resulting in multiple fatalities (9 deaths), all of which were residential fire incidents, and all victims were in the 0 – 4 year age group.

5.3.1.2 Fatality age, gender, and ethnicity

Younger children were at greatest risk of dying from fire-related injury, with over three-quarters of the victims being less than five years of age (15/19). A quarter of the victims were aged two years (5/19). The mean age of decedents was 3.5 years (range, 3 months to 12 years). The age specific fatality rate in the 0 – 4 year age group was 1.8 per 100 000. Rates in the other two age groups were not calculated due to insufficient numbers of deaths (Table 1.).

Table 1. Age-specific characteristics of unintentional fire-related fatalities occurring among children in the Auckland region.1989-1998.(*n*= 19)

Age group	Total	
	Number	Rate per 100,000
0 – 4 years	15	1.8
5 – 9 years	*	*
10 – 14 years	*	*
Total	**19**	**0.8**

* = fewer than 5 deaths, rates unstable

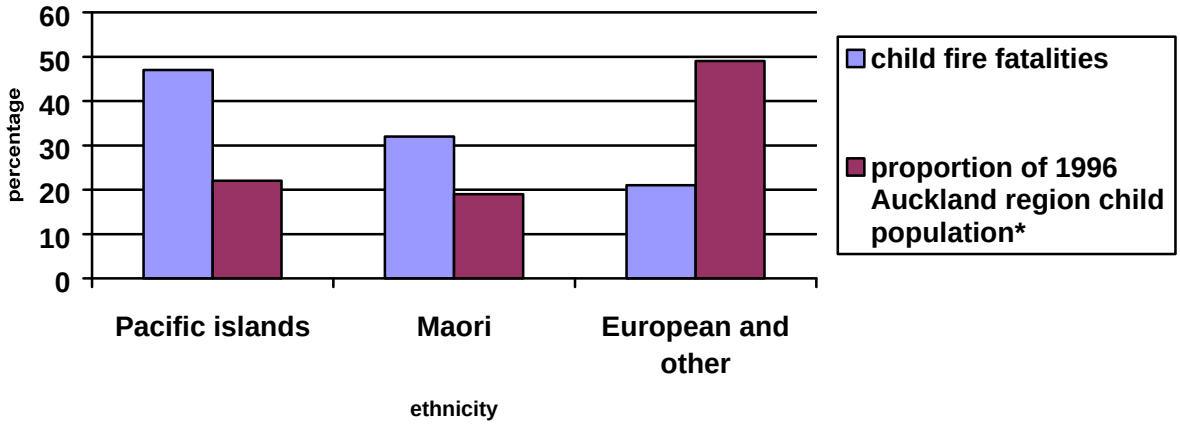
Almost three times as many male children (14/19) died of fire-related injury as female children (5/19).

Almost half (9/19) the fatalities occurred among children identified as of Pacific Islands descent, despite this group comprising only 18 percent of the 1991, and 22 percent of the 1996 Auckland Region child population [48] (Figure 3. See following page). Ethnic

specific rates were not calculated due to the low study numbers. All of the Pacific Islands fatalities occurred as a result of house fires.

Children identified as of Maori descent comprised nearly a third (6/19) of the fire-related fatalities, although they comprised 18 percent of the 1991, and 19 percent of the 1996 child population for the region [48]. Just under a quarter (4/19) of fatalities occurred in children of European descent who comprise 49 percent of the child population. Three out of the four car fire deaths occurred to children of European descent.

Figure 3. Ethnic proportions of child fire-related fatalities relative to ethnic composition of the Auckland region child population.1989-1998



*= 1996 census data [48]

5.3.1.3 Fatality socioeconomic status

Child fatality cases were not able to be geocoded to census meshblock level to analyse levels of deprivation due to low case numbers.

Of the 10 house fires that resulted in a total of 15 fatalities, five of the properties were state rentals, two were private rentals, two properties were owner occupied, and for one, the property ownership was unable to be established from the documentation reviewed. The numbers are insufficient to draw any meaningful conclusions, although state rental properties appear to be over represented.

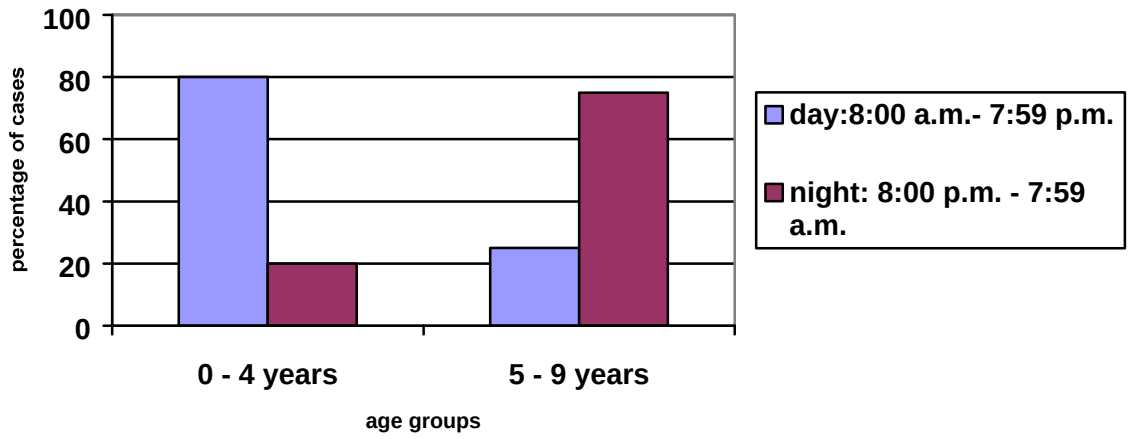
Presence or absence of a telephone was inconsistently recorded in the documentation reviewed, and therefore no conclusions could be drawn.

5.3.1.4 Fatality cause of injury

The 19 fatalities occurred in 14 fire incidents, of which 10 were residential fires (71.4%), the remainder were parked car fires. Ninety-three percent (13/14) of the fatal incidents occurred in the home (includes yard, outside buildings, and driveway). Ten (71.4%) of the 14 fatal fire incidents occurred on Fridays. All of the fatal residential fires occurred between the hours of 00:15 Friday and 10:00 hours Sunday. Figure 4 (see following page) shows the percentage of fatal fire incidents occurring during the day or night by age group. Eighty percent (8/10) of fatal fire incidents involving children aged less than five years, occurred during the day (8:00 a.m. – 7:59 p.m.). In seven out of

eight of these incidents match or lighter play was the source of ignition. In contrast 75 percent (3/4) of the fatal incidents involving children in the 5 – 9 year age group occurred during the night (8:00 p.m. – 7:59 a.m.).

Figure 4. Fatal fire incidents by time of day



There were 15 fatalities in 10 house fire incidents during the study period, a rate of 1.5 child fatalities per house fire. Of the ten fatal residential fires, two of the fires occurred in sleep-outs and one in a caravan. Five of the10 residential fires originated in a bedroom, or sleeping area. Eight of the ten residential fires occurred in the victims own home. In six of the 10 residential fires, smoke detectors were not recorded as being present. In the remaining four fires smoke detector presence or absence was not recorded in the reviewed documentation.

Of the four car fires, three occurred in residential property.

Ten (71.4%) of the 14 fatal fire incidents were a direct result of the actions of the victim or another child. With six (60%) of the ten residential fires being the direct result of the actions of the victim or other children.

In eight of the 14 fatal fire incidents match or lighter play was the cause of the fire. In seven out of the 10 fatal incidents involving children aged less than five-years, match or lighter play was the source of ignition. Match or lighter play was the most common cause of fatal residential fires (4/10), and the cause of all four fatal car fires.

Three of the fatal fires were as a result of electrical equipment including heaters. None of the incidents were as a result of careless disposal of smoking materials.

Almost three-quarters (14/19) of the victim's activity prior to injury was *playing*, and the remaining victims (5/19) were *sleeping* prior to the fatal incidents. There was no evidence to suggest that any of the fires were lit deliberately.

Fatality numbers were insufficient to analyse seasonal variation in occurrence of fatal fire events.

5.3.1.5 Outcome of injury

Seventeen (89.5%) of the 19 victims died at the scene, the remaining two died in hospital. Eleven of the 19 fatal fire victims had cause of death listed on the forensic pathology report as *effects of fire*, five listed as *smoke inhalation*, and two as *severe burns*. Of the 17 victims whose Total Body Surface Area (TBSA) of burn was recorded, 10 had *extensive burns*, three had *severe burns* recorded, the remaining four had 65% - 80% TBSA of burn recorded.

Thirteen of the victims had serum carboxyhaemoglobin saturation levels taken. These ranged from five percent to 64 percent, with a mean level of 33 percent.

Blood levels of cyanide were recorded in three cases.

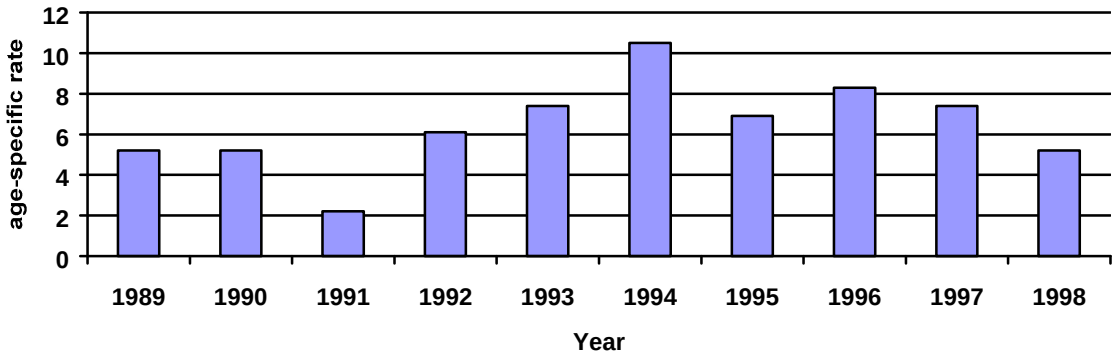
In the 13 cases in which the area of burn had been ascertained 12 had 80% or greater TBSA, and one victim had 65% TBSA. Six cases had no burn injury reported. The TBSA of the two cases admitted to hospital was 65%, and greater than 80%.

5.3.2 Fire-related hospitalisations

5.3.2.1 Overall hospitalisation results

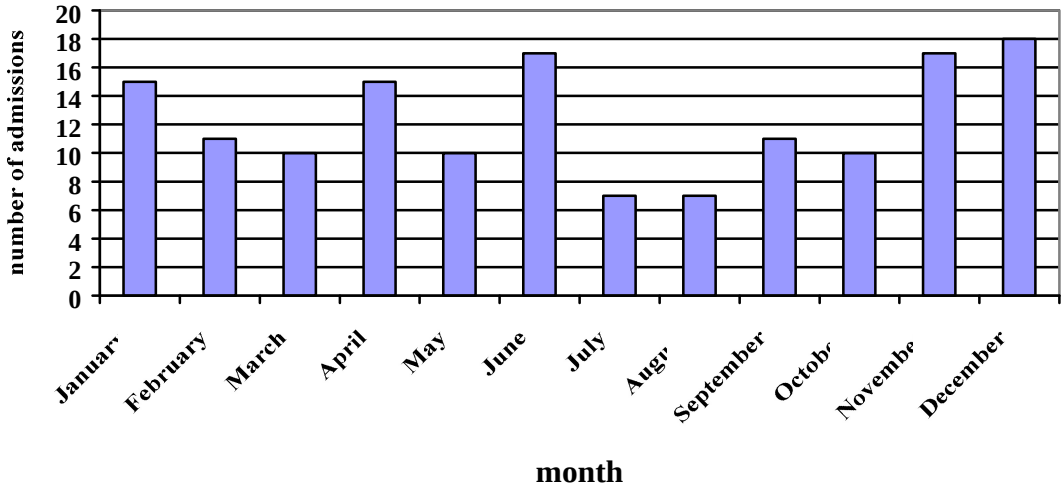
During the ten-year period of investigation, review of NZHIS hospitalisation data and Middlemore and Starship casemix records identified 148 unintentional fire-related hospital admissions among Auckland children. Figure 5 shows the crude rates of children hospitalised as a result of unintentional fire-related injury during the study period. There was an overall annualised average age-specific rate of 6.4 per 100 000. Numbers were insufficient to analyse trends over the 10-year period, although it is interesting to note the low numbers of hospitalisations in 1991.

Figure 5. Annualised crude rates per 100 000 of paediatric (0-14 years) unintentional fire-related Starship and Middlemore hospitalisations.1989-1998.



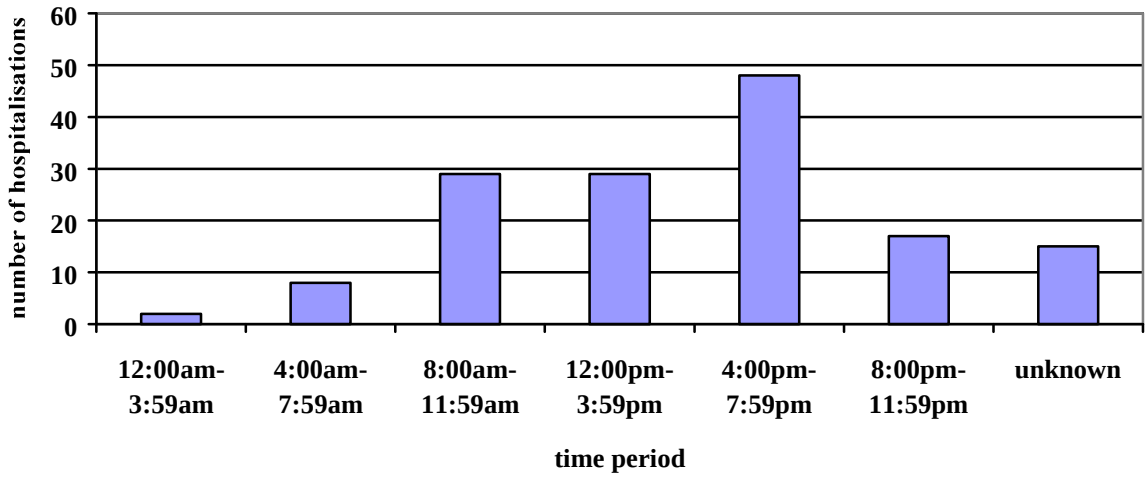
Monthly admissions are displayed in Figure 6. Despite June having the highest number of admissions, there appears to be an overall decline in hospitalisations during winter months and an increase over summer months.

Figure 6. Month of admission of paediatric fire-related Starship and Middlemore hospitalisations.1989 - 1998. *n* = 148



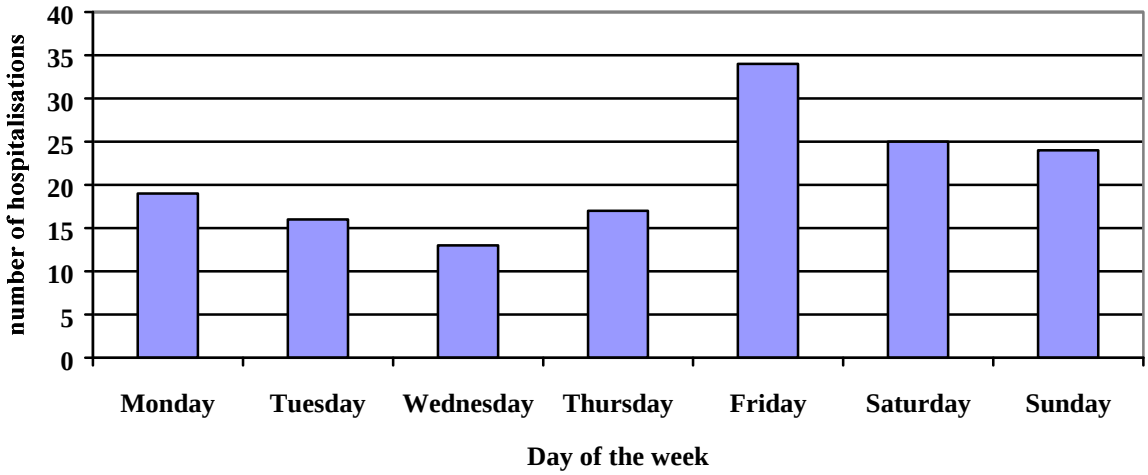
The distribution according to time of day injury occurred shows a peak during the 4:00 p.m. to 7:59 p.m. period (Figure 7. See following page).

Figure 7. Distribution of paediatric fire-related Starship and Middlemore hospitalisations by time of day. 1989-1998.(*n*=148)



The incidence of flame burns resulting in admission was relatively more common during weekends than during the week (Figure 8.). Incidents occurred most commonly on Fridays. Over half (56.1%) of the incidents occurred between Friday and Sunday.

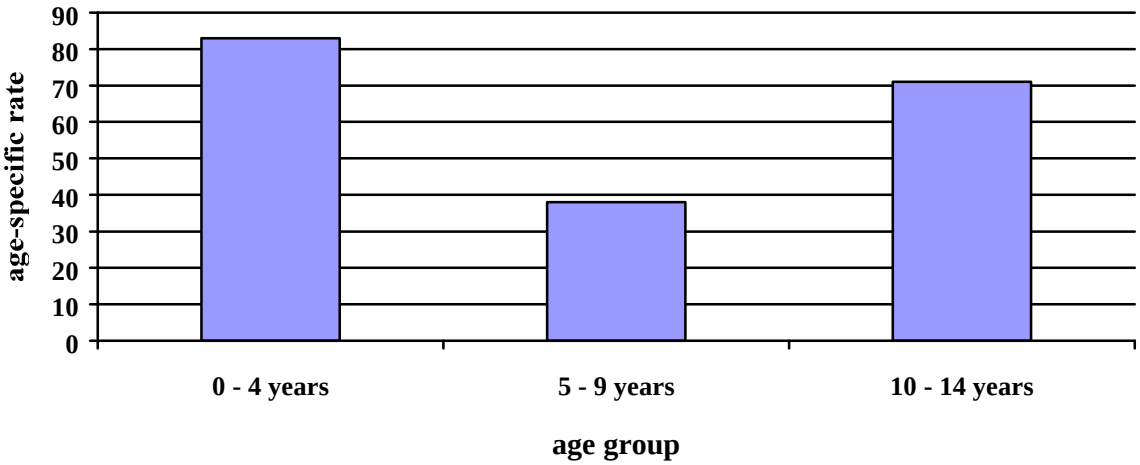
Figure 8. Distribution of paediatric fire-related Starship and Middlemore hospitalisations by day of the week. 1989-1998 (*n*=148).



5.3.2.2 Inpatient: age

The mean age of cases was 6.9 years (Standard Deviation (SD) = 4.8) with an age range from 3 months to 14 years. Forty-six percent (*n* = 68) of hospitalisations occurred in children under the age of five-years (Figure 9. See following page.). Age and gender-specific rates are displayed in Table 2 and Figure 9 (see following page).

Figure 9. Age and gender-specific distribution of paediatric fire-related Starship and Middlemore hospitalisations by age group. 1989-1998. (*n* = 148)



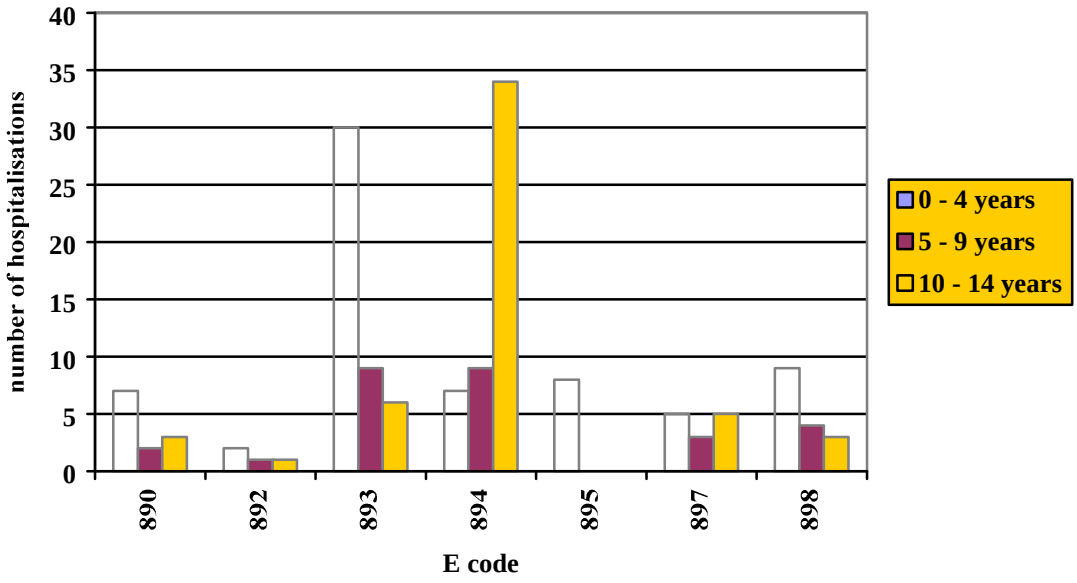
The highest rate of hospitalisation was observed in the 0 – 4 years age group, and the lowest rate observed in the 5 – 9 year age group (Table 2).

Table 2. Age-specific characteristics of paediatric Starship and Middlemore hospitalisations unintentional fire-related injuries. 1989-1998

Age group	Male Number	Rate per 100,000	Female Number	Rate per 100,000	Total Number	Rate per 100,000
0 – 4 years	43	10.3	25	6.3	68	8.3
5 – 9 years	20	5.2	9	2.4	29	3.8
10 – 14 years	43	11.7	8	2.3	51	7.1
Total	**106**	**12.7**	**42**	**3.8**	**148**	**6.5**

There appears to be an association between age and type of injury (Figure 10. See following page). The age pattern for E893 (ignition of clothing) shows a peak in the 0 - 4-year age group with the least numbers in the 10 - 14-year age group. The reverse pattern is seen for E894 (ignition of highly flammable material) with highest numbers seen in the 10 - 14-year age group and least in the 0 - 4-year group.

Figure 10. Distribution of mechanism of injury, and age in paediatric fire-related Middlemore and Starship hospitalisations.1989 – 1998. (*n* = 148)



E codes:

890: conflagration in private dwelling
892: car fire
893: accident caused by ignition of clothing
894: ignition of highly flammable material
895: accident caused by controlled fire in private dwelling
897: accident caused by controlled fire not in 898: accident caused by other specified fire and flames building/structure

5.3.2.3 Inpatient: gender

There were significantly more males (73 %) than females (27 %). The proportion of males was significantly higher than their proportion in the Auckland region child population ($p < 0.0001$). Age-specific rates for male and female are shown in Table 2 (section 5.3.2.2). Overall age specific rates for males exceeded those for females (RR 2.41, 95% CI 1.69 – 3.44, $p = 0.0000006$).

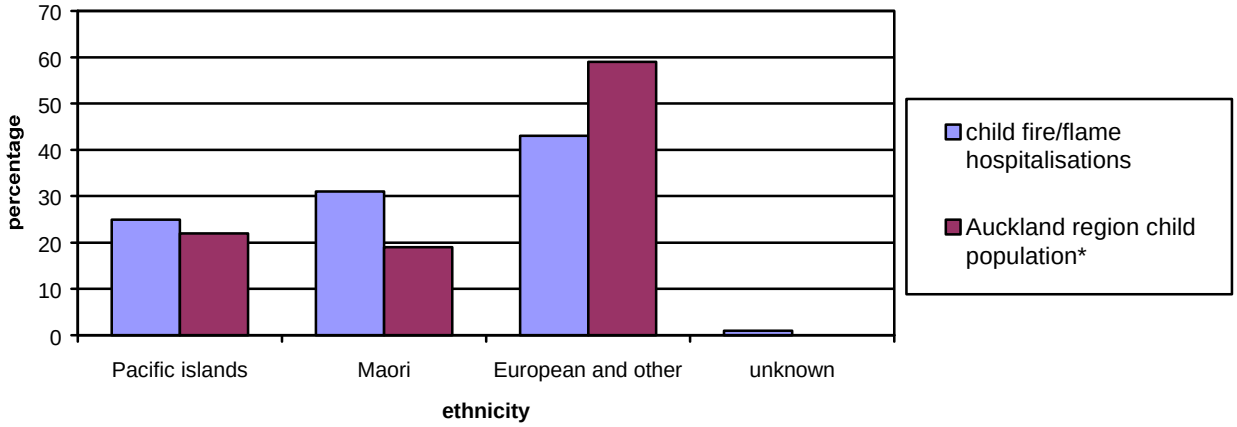
The pattern of injury differs between males and females. In males the highest rate is in the 10 – 14 year age group, while in females the 0 – 4-year age group has the highest rate. Poisson regression shows an interaction occurring between age and sex ($p = 0.03$).

In both sexes there are significant differences (males $p = 0.004$, females $p = 0.007$) between the age groups. In males the 10 - 14 year age group rate is more than double the rate of the 5 – 9 year age group. In females the rate in the 0 – 4-year age group is nearly triple that of the 10-14 year age group.

5.3.2.4 Inpatient: ethnicity

Ethnicity data was abstracted from the hospital admission form, self-identified by the child's caregiver. Figure 11 (see following page) displays the ethnic representation of hospitalisation cases. Maori children appear to be over represented among hospitalisations.

Figure 11. Ethnic proportions of paediatric fire-related Middlemore and Starship hospitalisations relative to the ethnic composition of the Auckland region child population.1989 – 1998. (*n*=148)



*= 1996 census data [48]

Of the 37 Pacific Islands children hospitalised, 16 were Samoan, 13 Tongan, six-Rarotongan, and two-Niuean.

Calculation of age specific ethnicity rates excluded the two children with no ethnicity data recorded. Age specific hospitalisation rates for Maori were twice those of non-Maori (RR 2.04, 95% CI 1.44 – 2.89, p = 0.00004) (Table 3.).

Table 3. Numbers of hospitalisations and age-specific rates (per 100 000) from paediatric fire-related Middlemore and Starship hospitalisations 1989-1998, by ethnicity and gender.

Total hospitalisations	Rate	Maori hospitalisations	Maori rate	Non-Maori hospitalisations	Non-Maori rate
146	6.1	46	10.9	100	5.3

Data source: ethnic denominators – Statistics New Zealand

5.3.2.5 In patient: socioeconomic status and measures of deprivation

Presence or absence of a telephone is a measure of socioeconomic status, this variable was inconsistently recorded in the documentation reviewed, and therefore no conclusions could be drawn regarding the socioeconomic status of cases on this basis.

Of the 148 fire-related paediatric hospital admission cases, 131 (88.5%) were able to be geocoded to census meshblock level, for the address where incident occurred. Excluded cases were those where a street address where the incident occurred was either not documented, or not available for example in incidents that occurred in parks. Mapping of incidents to NZDep96 deciles is displayed in Figure 12 at the end of this section. Of the remainder, in six cases the address of incident was unknown, four did not have a street number documented, and in seven their street address may have been incorrect and was therefore not recognised.

During the 10-year period fire-related incidents resulting in paediatric hospital admission, appear to have occurred disproportionately in census meshblocks with high levels of social and economic deprivation, as assessed by NZDep96 indices of deprivation (Table 4.). Of the 131 cases whose address where the incident occurred was geocoded, 53.5% (n = 70) of the incidents occurred in dwellings in the most deprived (NZDep levels 9 and 10) Auckland meshblocks (Table 4.). In contrast, 10.7 % (*n* = 14) of the geocoded incidents occurred in dwellings in the least deprived (NZDep levels 1 and 2) Auckland meshblocks. It should be noted that increasing numbers observed in the higher deciles do not take into account the numbers of children residing in each decile and should be interpreted with caution. Further analysis is needed to examine rates for each decile.

Table 4. Number and percentage of child fire-related hospital admissions in Auckland occurring in census meshblocks at each decile level of social and economic deprivation, as measured by NZDep indices of deprivation. 1989-1998. *n*=131

Index of deprivation	Level of Deprivation	Number of hospitalisations	Percentage of incidents
1993-1998 NZDep96	1	9	6.9
	2	5	3.8
	3	4	3.0
	4	4	3.0
	5	4	3.0
	6	9	6.9
	7	9	6.9
	8	17	13.0
	9	31	23.7
	10	39	29.8

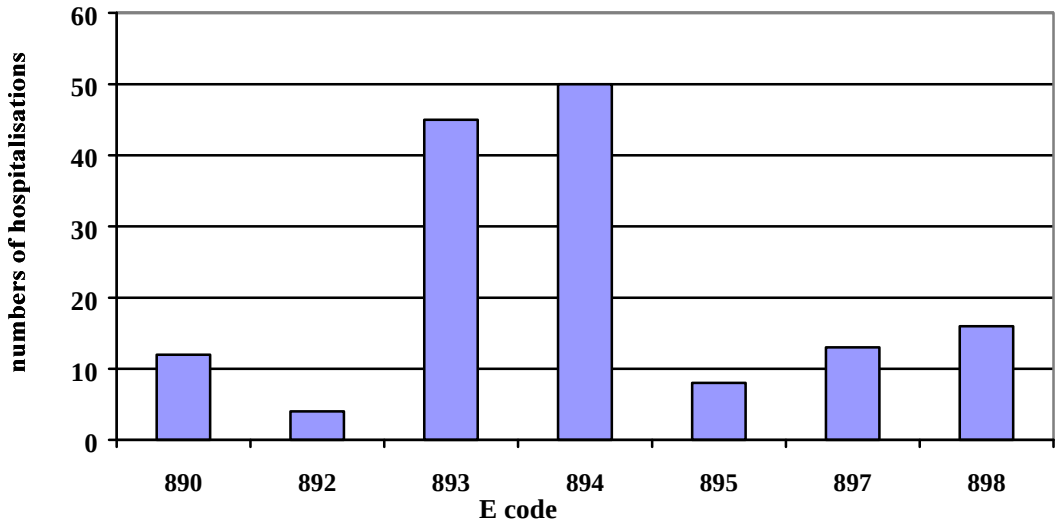
Figure 12. Paediatric unintentional fire-related Starship and Middlemore hospitalisations by location of injury and NZdep96 score. 1989-1998

5.3.2.6 Inpatient: mechanism of injury

Cause of injury

Ignition of highly flammable material (E894) was responsible for a third (33.7%) of hospitalisations (Figure 13). Petrol was by far the most common inflammable agent causing flame burns, and was involved in a quarter (24.3%) of all fire-related burn admissions to hospital. Petrol was frequently used to start rubbish fires with 17 percent (*n* = 25) of paediatric fire-related hospitalisations resulting from involvement with rubbish fires.

Figure 13. Mechanism of injury for paediatric fire-related Starship and Middlemore hospitalisations.1989-1998. *n* = 148



E codes:
890: conflagration in private dwelling
892: uncontrolled fire (includes car fire)
893: accident caused by ignition of clothing
894: ignition of highly flammable material
895: accident caused by controlled fire in private dwelling
897: accident caused by controlled fire not in building/structure
898: accident caused by other specified fire and flames

Ignition of clothing (E893) was responsible for 30% (*n* = 45) of hospitalisations (Figure 13). It is interesting to note that using the ICD-9-CM classification of injuries, incidents where a victim's clothing ignites as a result of fire/flame can be coded in three ways. The code E893 is assigned for accidents caused by ignition of clothing (excludes conflagration and highly inflammable material), E894 includes ignition of clothing with highly inflammable material, and E890-892 includes ignition of clothing from conflagration. In this study cases where clothes ignited (E893, E894) accounted for 39.9% (*n* = 59) of patients and yet if examining the data purely by the clothing ignition code E893, the percentage would be lower at 30.4% (*n* = 45).

There were 10 house fire (E890) incidents resulting in 12 hospitalisations (including one fatality), a ratio of injuries per fire of 1.2:1. Nine out of 10 incidents occurred between the hours of 10:00 p.m. and 8:00 a.m. Seven of the incidents occurred either on a Friday or Saturday. Six of the incidents originated in a bedroom. Two incidents were as a result of faulty electrical equipment, two cigarettes related incidents, in two incidents

the cause was not recorded in the reviewed documentation, and the remaining four incidents were other causes.

There were four car fire victims (one of whom died). Children playing with matches/lighters started all of the car fires.

No cases in the study were identified as potential intentional burns from the documentation reviewed.

In 88.5% (*n* = 131) of cases the injury was as a result of the actions of the victim or another child. In 80.4% (*n* = 119) the injury was as a direct result of the actions of the victim.

Source of ignition

The source of ignition was identified from narrative descriptions of the injury event contained in the documentation (Table 5). Matches or cigarette lighters were the agent most commonly involved, and were responsible for 40.6% (*n* = 60) of injuries. Smoking was directly responsible for only 4.7% (*n* = 7) of incidents in this study.

Table 5. Source of ignition for paediatric unintentional fire-related injury admissions to Starship and Middlemore hospitals. 1989-1998.(*n*=148)

Source of ignition	% (*n*)
Matches/cigarette lighter:	40.6 % (*n*=60)
Flame: outside fire = 30 inside fire = 12 cooking oil = 4 candle: = 5	35.1 % (*n*=52)
Electrical: other = 4 radio = 2 stove = 3	6.8% (*n*=10)
Smouldering combustion (embers)	**6.0% (*n*=9)**
Cigarette	**4.7% (*n*=7)**
Other	**4.1% (*n*=6)**
Unknown	**2.7% (*n*=4)**
	100% (*n*=148)

Location of injury occurrence

Ninety-three percent (*n* = 137) of injuries occurred in the home. In 20.4% (*n* = 28) of cases, the location within the home was unable to be ascertained from the documentation reviewed. Of the 109 incidents where the location within the home was

documented, 59.6 % (*n* = 65) of injuries occurred outside the dwelling, whilst 40.4% (*n* = 44) occurred inside ("sleepout" was classified as *inside*) (Table 6).

Table 6. Location in the home where burn injuries occurred (*n* = 137).

yard / garden	living area	garage/ outbuilding	bedroom/ sleepout	kitchen	other outside	bathroom	unknown
38.7 % (*n* = 53)	16.1 % (*n* = 22)	7.3 % (*n* = 10)	9.5 % (*n* = 13)	5.8 % (*n* = 8)	1.5 % (*n* = 2)	0.7 % (*n* = 1)	20.4 % (*n* = 28)

Level of supervision

Supervision was difficult to ascertain as the information was inconsistently recorded and therefore not reliable enough a variable to be analysed.

Clinical course

Table 7 (see following page) summarises the identified characteristics of the child and his/her clinical course by the cause of fire-related injury. Ignition of clothing (E893) had the highest morbidity of the causes of injury in the study as indicated by: the highest median length of stay; the highest percentage of cases undergoing procedures requiring GA; the second highest number of admissions; and the second highest average TBSA.

In contrast, conflagration in private dwelling (house fire, E890) had the highest mortality in the mechanisms of injury in the study, had the lowest median length of stay and the least cases requiring procedures under GA.

Table 7. Cause of injury, age and gender distribution, length of stay, burn size, and number of cases who underwent general anaesthesia (GA) in paediatric fire-related Starship and Middlemore hospitalisations.1989-1998.*n* = 148

Cause of injury (E code)	number (M/F) M:F	average age (yrs) (range)	hospital fatalities	non-hospital fatalities	average TBSA burn (%) (range)	median length of stay (days) (range)	number of cases who underwent GA (*n*)
uncontrolled fire (includes car fire *n*=4) (892)	4 (3/1) 3:1	6.0 (2 –12)	1	3	25.0 (3 – 65)	4.5 (2 – 45)	1
ignition of clothing (893)	45 (27/18) 2.1:1	4.9 (0 -14)	0	0	10.6 (1 - 30)	12.0 (1 - 70)	26
ignition of highly flammable material (894)	50 (42/8) 5.3:1	10.4 (2 – 14)	0	0	9.2 (2 - 30)	5.0 (1 – 56)	12
conflagration in private dwelling (890)	12 (8/4) 2:1	4.9 (0 – 14)	1	14	10.0 (0 – 80)	1.0 (<1 - 22)	1
controlled fire in private dwelling (895)	8 (5/3) 1.7:1	1.25 (0 – 3)	0	0	4.9 (1 - 20)	2.5 (1 - 21)	2
other specified fire and flames (898)	16 (11/5) 2.2:1	5.3 (0 - 13)	0	0	4.4 (1 - 30)	2.0 (0.16 – 35)	6
controlled fire not in building or structure (897)	13 (10/3) 3.3:1	7.5 (1 - 14)	0	0	2.9 (1 - 8)	5.0 (1 - 14)	4

5.3.2.7 Inpatient: extent and severity of injury

In 31 cases (20.9%) there was no Total Body Surface Area (TBSA) burned recorded. In these cases the researcher estimated the TBSA, using a modified Lund and Browder chart [88] used by Middlemore hospital. In 29 of the cases with estimates of TBSA, the TBSA was 5%, and the remaining cases had an estimated TBSA of 15% and 10% respectively. The mean TBSA for subjects with a documented TBSA (n = 117) was 8.8% (range 0 - >80%). Sixty-seven percent (n = 78) of cases had a TBSA 10%, 83.7% (n = 98) a TBSA of 20%, and 17.9% (n = 21) had a TBSA 20%. The six patients (5.1%) with a TBSA of 30% survived. The two cases with a TBSA > 60% both died in hospital.

The burn sites most commonly involved were the limbs and face. Burn thickness was inconsistently recorded and therefore no data was collected. Thirty-five percent of patients (n = 52) had procedures requiring general anaesthesia. Grafting and debridement were the most commonly performed procedures.

Smoke inhalation was ICD coded as a diagnosis in 6.8% (n = 10) of cases, seven had been involved in house fires, two involved bedding on fire, and one was a car fire victim. There was one smoke inhalation related fatality. Carboxyhaemoglobin levels were obtained for seven cases they ranged from 0 % - 18%.

Of the nine patients who were treated at both Starship and Middlemore hospital, four were injured as a result of highly flammable material, three were house fire victims one was injured by a controlled inside fire, and one walked on hot embers. The victims had a mean TBSA of 10.2 % (range 4 - 28%). Two victims had TBSA > 10%, one victim with 28% TBSA was admitted to Starship for one day (total length of stay 13 days). The second victim with TBSA 20% was admitted to Starship for 10 days out of a total hospital stay of 21 days. There were no fatalities in this group.

5.3.2.8 Inpatient: outcomes

There were two fatalities, a house fire victim and a car fire victim, giving a mortality of 1.4%.

Median length of hospital stay for patients in this study was five days, with a range of <1 to 70 days. There was a total period of 1564.66 patient-days in hospital of which 56 were spent in the Intensive Care Unit, and 1514.66 days were in a hospital ward. Fifteen patients required Intensive Care Unit stays (all at Middlemore Hospital Intensive Care Unit), the longest of which was 16 days. In ten of these cases the victims clothing ignited (E893 Ignition of clothing = 6, E894 Ignition of highly flammable material= 4).

Data was collected on patient's level of disability on discharge, and need for ongoing treatment. Both of these fields were inconsistently recorded and were therefore not analysed.

6 Discussion

This chapter discusses the descriptive study findings and methods, and then links them to the literature review findings. The chapter is in two sections. Section one summarises the study findings. Section two relates the findings of the descriptive study to the national and international published literature on fire-related injury.

6.1 Discussion of descriptive study

6.1.1 Summary of study findings

6.1.1.1 Summary of fatalities

It should be noted that low fatality numbers in the study restrict analysis of data, and findings should be interpreted with caution.

During the study period 19 children died from unintentional fire-related injury in the Auckland region.

Demographics

- age-specific average annualised rate was 0.8 per 100,000.
- younger children were at greatest risk of dying from fire-related injury. The mean age for fatalities was 3.5 years.
- almost three times as many male children died as female.
- almost half of the descendants identified as Pacific Islands (22% of Auckland region's child population in 1996), and nearly a third identified as Maori (19% of Auckland region's child population in 1996).

Mechanism of injury

- four incidents resulted in multiple fatalities
- the 19 fatalities occurred in 14 fire incidents, 10 residential fires, and four-parked car fires.
- 93% of incidents occurred in the home (includes yard, outside buildings, and driveway). The house fire fatality rate was 1.5 child deaths per house fire.
- 50% of the 14 house fire incidents originated in a bedroom or sleeping area.
- match/lighter play was the most common cause of fatal residential fires (40 %), and the cause of all four-parked car fires.
- 80% of fatal fires involving children aged less than five-years, occurred during the day (8:00 a.m. – 7:59 p.m.), in contrast 75% of fatalities in the 5-9 year age group occurred during the night.

Outcomes

- 90% of victims died at the scene. Of the 17 victims with a Total Body Surface Area (TBSA) burn recorded, all had 65% TBSA burn.
- 13 victims had carboxyhaemoglobin saturation levels recorded these ranged from 5 – 64 % (mean 33 %).

6.1.1.2 Summary of hospitalisations

During the study period 148 children were hospitalised (primary admissions) as a result of unintentional fire-related injury in the Auckland region. There were 29 admissions to Starship, 110 to Middlemore, and nine cases were admitted to both hospitals. Hospitalisations were analysed as one group, regardless of admitting hospital.

Demographics

- age-specific average annualised rate was 6.4 per 100,000.
- mean age for hospitalisations was 6.9 years.
- highest rate of hospitalisation was observed in the 0 – 4 year age group (8.3 per 100,000), and the lowest in the 5 – 9 year age group (3.8 per 100,000).
- male age-specific rate exceeded the female rate (RR 2.41, 95% CI 1.69 – 3.44, p = 0.0000006). In males the highest injury rate was in the 10-14 year age group, in females the rate was highest in the 0 – 4 year age group.
- Maori was the ethnic group most over represented with their admission rates being twice those of non-Maori children.
- there appeared to be an overall decline in admissions during winter months and an increase over summer months.
- time of day injury occurred, peaked during the 4:00 p.m.- 7:59 p.m. period.
- incidents occurred most commonly on Fridays (22.9%).
- during the study period incidents resulting in hospital admission appear to have occurred disproportionately in areas with high levels of social and economic deprivation.

Mechanism of injury

- 93% of injuries occurred within the home environment (included yard, outbuildings, and driveway).
- three leading causes of injury as a proportion of hospitalisation cases were: ignition of highly flammable material (E894) 33.8 %, ignition of clothing (E893) 30 %, other specific fire/flames (E898) 11 %. Overall 30 % of injuries were caused by clothing igniting, either with or without the involvement of petrol (E893, E894). There were 10 house fire incidents, resulting in an injury per fire ratio of 1.2:1.
- there appears to be an association between age and cause of injury. For the cause of injury E893 ignition of clothing, the age pattern shows a peak in the 0 - 4-year age group with the least numbers in the 10 - 14-year age group. The reverse pattern is seen for ignition of highly flammable material (E894).
- in 89 % of all hospitalisation cases the injuries were as a direct result of the actions of children. Matches/lighters were responsible for 41 % of injuries.
- the majority of incidents were domestic (93 %) (includes yard, garage, sleepouts), with 60% occurring outside.

Outcomes

- there were two fatalities (one car fire, one house fire), a mortality of 1.4%.
- mean TBSA of burn for cases with a documented value was 8.8% (range 0 - >80%). Sixty-seven percent of cases had a TBSA burn of 10%, 18 % of cases had a TBSA burn of 20%. The two cases with a TBSA of burn of >60% died. Thirty five percent of cases required general anaesthesia for burn-related procedures.

Seven percent of cases received a diagnosis of smoke inhalation. Ignition of clothing (E893) had the highest morbidity of all the causes of injury in the study (highest median length of stay; highest percentage of cases undergoing procedures requiring GA; second highest number of admissions; and the second highest average TBSA).

- median length of stay was five days, and there was a total of 1564.66 patient days.

6.2 Comparisons with national and international data

6.2.1 Fatalities

Despite the low fatality numbers in the descriptive study, the demographic characteristics of childhood unintentional fire-related fatalities observed in the Auckland region during the study period, are similar to those observed in other published studies from developed countries. Three quarters of descendants were in the 0 – 4 year age group. This matches findings by Parker *et al.* of 75 percent of fatalities in this age group, in a study of 57 New Mexico child fire fatalities [20]. Rates in this study in the 0 – 4 year age group are six times higher than those among 10-14 year olds, the exact pattern was observed in the US by Grossman in 1996 [36].

The mean age of victims in this study was 3.5 years, similar findings to that observed by Parker *et al.* in New Mexico, where a mean age of 3.75 years was reported [20]. Age-specific rates in all three age groups in this study were lower than US rates for unintentional residential fire/flame mortality in children in 1996[36]. Seventy-three percent of children were male in this study, compared with 66 percent in the New Mexico study [20].

In several studies in America [37, 57, 64], as well as in New Zealand [44, 62], ethnic minorities were over represented in fire fatality statistics. In this study Pacific Islands and Maori children appear to be over represented, the exception being parked care fire fatalities in which three of the four victims were European. Data for Maori and Pacific Islands children needs to be analysed independent of the potential confounding effect of socioeconomic status.

Ten of the 14 fatal fire incidents in this study occurred on Fridays. This is consistent with findings by Lamm *et al.* in an analysis of 10-years of residential fire-related fatality data in the Auckland region that observed 25 percent of fatal fire incidents occurred on Fridays [39].

In the under five age group 80 percent of fatal fire incidents occurred during the day. This is higher than the 51 percent reported in an American fire service report of fatal residential fires involving children [57]. However 75 percent of the fatal incidents involving children in the 5 – 9 year age group in this study occurred during the night, consistent with the findings in the report [57].

A strong association exists between poverty and childhood injury [19, 33, 36, 89-92]. Housing tenure is an indicator of socioeconomic status. In this study tenure data was only available for fatal house fire incidents. Almost three-quarters (7/10) of the house

fires involved in fatal incidents in this study were rental properties. This finding correlates with Lamm *et al.*'s analysis of Auckland residential fires showing those living in rental accommodation are at higher risk of dying in a house fire than those living in privately owned property [39].

Some differences were apparent in the cause of unintentional fatal fire-related injuries in this study from findings in other published child burn studies. Over a quarter (4/14) of the fatal fire incidents were as a result of children playing in cars unsupervised with matches or lighters. Parker *et al.* in the New Mexico study reported only 3.5 percent of child fire deaths attributed to fires in cars [20]. No other specific reference was made in the published literature reviewed to fires in parked cars, as a cause of injury in fatal domestic fire incidents among children. A possible explanation for this may be numbers for this mechanism in other studies have been insignificant. In view of the contribution of car fires in this small study, it is an area that warrants further investigation in both a New Zealand and international context.

There was a lower percentage of fire fatalities as a result of conflagration in a private dwelling (71 percent) in this study, compared with 94 percent of unintentional fire-related deaths among children and adolescents in America [36].

America has a higher rate of smoking than New Zealand, and perhaps not surprisingly an American study reported careless disposal of cigarettes as the source of ignition in 14 percent of fatal fires involving children [29]. In contrast no house fires in this study started as a direct result of cigarettes. What are surprising in this study are the 70 percent of fatal fire incidents involving children aged less than five-years of age in which match or lighter play was the source of ignition. This compares with only 33 percent of incidents in an American study [29]. Correspondingly 70 percent of house fire incidents in the 0 – 4 year age group in this study were as a direct result of the children's activities (ie. match/lighter play). This compares with only 40 percent in a Scottish study of house fire fatalities involving children [21].

In three out of four fatal fires in this study involving children playing with matches, fire originated in a bedroom. This is consistent with a US finding that over half of fatal fires started by children playing with matches/lighters originate in bedrooms [57].

In the present study there was a fatality rate of 1.5 child deaths per house fire. This is consistent with Squires and Busuttil's rate of 1.4, in their study of 168 child house fire deaths during a 10-year period in Scotland [21]. In contrast, the mortality rate for the hospitalisations in this study was 1.4 percent, lower than that of 9.2 percent reported in an American paediatric burn hospitalisation analysis of 163 flame burns [6].

Eighty-nine percent of victims in this study died at the scene. This is consistent with international published studies [20, 21]. The majority of fire-related fatalities die as a result of smoke inhalation [6, 20].

6.2.2 Hospitalisations

In general the analysis of fire-related injury hospitalisations in this study conforms to other published studies carried out in New Zealand and developed countries. The mean age of cases was 6.9 years, slightly younger than the 7.3 years observed in fire/flame victims as part of a French study of 937 paediatric burn hospitalisations [10]. The highest rate of fire-related injury requiring hospitalisation was observed in the 0 – 4-year age group, accounting for 46 percent of admissions in this study. This is consistent with rates in the US [36], but differs from an Australian study that reported a similar proportional distribution of flame burns throughout the three age groups [7].

Overall male hospitalisation rates in this study exceeded female rates, a finding consistently reported in the child burn injury literature [4, 6, 7, 9, 10, 12, 17, 18, 55]. The age-specific male rate in the 10 – 14 year age group was five times that of the female rate in the same age group. Similarly an Icelandic study of 290 paediatric burn admissions reported a male to female ratio of 4.0 in the 10-15 year age group [13].

Maori hospitalisation rates were twice those of non-Maori, a lower ratio than the triple reported by Duncanson *et al.* for domestic fire injuries for all ages treated in New Zealand hospitals [62]. Higher fatality and hospitalisation rates for Maori and Pacific Island children than non-Maori and non Pacific Island children in this study may have been confounded by socioeconomic factors. Data for these two groups needs to be analysed independent of the potential confounding effect of socioeconomic status. Findings from this literature review and descriptive study, would support the consideration of some the following factors that may be confounding the effect of ethnicity on fire-related injury rates among children: hazardous environments, poor/inadequate housing, limited access to resources, decreased fire safety knowledge, and maternal characteristics.

Houses in disadvantaged meshblocks in the Auckland region appear to be over represented as places where paediatric fire-related injuries requiring hospitalisation occur. This is consistent with findings from burn injury studies in developed countries showing burn injury rates are higher in areas of social deprivation [18, 37, 91].

The percentage of hospitalisations that were injured as a result of playing with matches/lighters was 41 percent in this study. This is higher than the 32 percent of fires resulting in child injuries caused by 'playing fires' reported in America [57]. The findings from this descriptive study regarding higher numbers of incidents caused by children playing with matches/lighters than observed in America, despite New Zealand having lower smoking rates, is of concern and requires further investigation.

In this study 52 percent of injuries related to inflammable materials occurred in males aged 12-14 years. Petrol was by far the most common flammable burn-causing agent, consistent with findings observed by Pegg *et al.* in a study of burns due to domestic flammable agents [67]. This also correlates with a New Zealand study by Waller *et al.* that reported large number of fuel ignition related injury in young males [28].

Eighteen percent of cases in this study had a TBSA burn of 20% or greater. This is similar to a finding by Ray in a study of burns in children under five –years of age

admitted to hospital in Ontario, Canada who observed the mean TBSA for flame burns was 21% compared with 10.4% for scalds (one-way ANOVA, $p = 0.04$) [8].

7 Implications of literature review and descriptive study findings

This chapter discusses implications arising from a combination of information obtained from the literature review, and the results of the descriptive study. The chapter is in three sections. Section one discusses recommendations for injury prevention. Section two discusses the potential modifications to injury data sources used in the descriptive study. The chapter closes with section three in which directions for future research are examined.

7.1 Prevention

Recommendations for prevention of fire-related injury have been identified from the review of the literature, adapted for the New Zealand context, and combined with the information identified in the descriptive study. The recommendations will be discussed from an educational, environmental, and regulatory perspective. Following this, issues related to fire safety technology will be reviewed. The section closes with an introduction to the concept of a 'pyrogenic' environment.

An apparent increased risk of fire mortality experienced by Pacific Island children, and fire morbidity experienced by Maori children in Auckland in this study, requires further investigation. And where appropriate the development of culturally appropriate and effective fire prevention strategies to target these groups.

Recommendation

1) The New Zealand Fire Service Commission develops where appropriate fire prevention initiatives in partnership with Maori ensuring the principles of the Treaty of Waitangi are adhered to. This process will be aided by the establishment of Maori liaison staff within the New Zealand Fire Service to help develop and evaluate fire prevention initiatives relevant for Maori.

2) The New Zealand Fire Service Commission develops where appropriate, fire prevention initiatives in partnership with Pacific Islands groups. This process will be aided by the establishment of Pacific Island liaison staff within the New Zealand Fire Service to help develop and evaluate fire prevention initiatives relevant to Pacific Island communities.

It should be noted that many injury prevention initiatives have important human and financial resource implications. It is imperative that interventions are adequately evaluated to establish effectiveness and cost-effectiveness of current and future fire-related injury prevention interventions [78, 93]. In addition Deal *et al.* stress the importance of information on the cost effectiveness of fire injury prevention strategies, to better inform public debate on the merits of these interventions [82].

7.1.1 Educational

Raising awareness of fire-related childhood injury risk among children and care-givers, and educating this group regarding ways to reduce that risk are vital injury prevention components. Integral in this process is the dissemination of relevant information to

individuals and agencies involved in the care and well-being of children and their families.

Recommendation

3) The New Zealand Fire Service Commission ensures that findings of this research are disseminated among agencies and individuals concerned with the well-being of New Zealand children.

4) The New Zealand Fire Service Commission liases with those agencies and individuals to incorporate fire safety strategies into individual and population based health promotion strategies for children. Relevant agencies and authorities include: Plunket, Safekids, early childhood education providers, the Commissioner for Children, the Ministry of Youth Affairs, the Ministry of Education, Te Puni Kokiri, the Ministry of Pacific Island Affairs, Maori and mainstream health service providers including Public Health service providers, and Maori and mainstream social service providers.

Continued efforts are needed to educate parents and children regarding the dangers associated with match or lighter play and storage. A fire knowledge survey conducted for the New Zealand Fire Service in 1999 found that in 35 percent of households children had access to matches or lighters. In addition 37 percent of children described by the parents as old enough to be left with a lighter or matches were less than eight years of age [94].

Recommendation

5) The New Zealand Fire Service Commission continues to resource effective initiatives to educate service providers, caregivers, and children regarding the dangers of children having access to, and playing with matches and lighters.

6) The New Zealand Fire Service Commission includes in fire safety educational material targeted at children and their families advice regarding the inappropriateness of cars as play areas for children, and recommending the locking of parked cars in domestic properties.

7.1.2 Environmental

The incidence of morbidity and mortality rates resulting from petrol related fire-related injury, especially in the adolescent age group, requires a multi-disciplinary and multi-faceted approach to improve the design of petrol containers and to educate young people and their parents of the hazards associated with inflammable liquids [29]. Agencies involved could include injury investigators, teachers, behavioural psychologists, petrol companies, gas utility providers, petrol container manufacturers, and chemical engineers.

Kennedy *et al.* made the following recommendations to address the issue of improper storage of petrol for home use. The development of national standards for petrol can design; warning labels attached to equipment that uses petrol to advise petrol should not be stored within 50 feet of a naked flame (eg. pilot light, BBQ, open fire); and raising of public awareness regarding the risks associated with the use of petrol in the home

environment [95]. It is recommended that a similar approach be undertaken in New Zealand.

Recommendation

7) The New Zealand Fire Service Commission supports the development of effective prevention strategies to address petrol-related injuries among adolescents including the safe storage of petrol for domestic use.

The introduction of flame retardant sleepwear legislation has impacted on the reduction in morbidity and mortality associated with nightwear flame-related injuries among children. But clothing ignition remains a significant factor in the severity of fire-related injury among children, and warrants investigation into the feasibility of mandating flame retardant material to be used in the manufacture of young children's clothing.

Recommendation

8) The New Zealand Fire Service Commission liases with the Ministry of Consumer Affairs regarding the possibility of flammability standards for children's clothing in line with those in existence for sleepwear.

Insurance companies should change underwriting and claims reimbursement policies to emphasise fire prevention, for example presence of hard wired smoke detectors or sprinkler systems could result in a lower premium.

Recommendation

9) The New Zealand Fire Service together with the Insurance Council of New Zealand explores the feasibility of premium lowering incentives for clients with hard-wired smoke detectors, and domestic sprinkler systems in place.

7.1.3 Legislation and regulation

The introduction of the compulsory installation of hard-wired smoke alarms into all new homes should be incorporated in to the New Zealand Building Code. In conjunction with this legislation could be introduced requiring landlords to install smoke detectors/sprinkler systems in residential rental properties. A financial incentive could be provided for this.

Recommendation

10) The New Zealand Fire Service Commission supports mandatory installation of hard-wired smoke alarms in new dwellings, and investigates the feasibility of legislation to ensure landlords have smoke detectors in place in residential rental properties.

Housing New Zealand currently has battery operated smoke alarms in single dwellings and hard-wired alarms in multi-complex residential buildings. The installation of hard-wired smoke alarms in all residential Housing New Zealand dwellings would be beneficial. The New Zealand Fire Service currently undertakes the role of an

independent regulatory agency with authority to regulate the fire safety of rest homes this role could be expanded to encompass state residential dwellings.

Recommendation

11) The New Zealand Fire Service Commission investigates the applicability of retrofitting sprinkler systems in dwellings managed by Housing New Zealand Limited.

7.1.4 Technology

Problems exist with the long-term maintenance of fire prevention technology, particularly smoke alarms. Hard wiring of smoke alarms is an alternative to the problems associated with battery replacement in smoke alarms. But it is an expensive option for most homeowners. Opportunity may exist for subsidising the cost of hard-wiring smoke alarms, or alternatively councils offering a form of rebate if ratepayers have hard-wired alarms in their homes.

Similarly sprinkler systems, proven to be effective in extinguishing fires, are expensive to install. Costs of this system need to be decreased to make them a more affordable option.

Recommendation

12) The New Zealand Fire Service Commission investigates opportunities to reduce the costs associated with installation of fire prevention technology.

7.1.5 The 'pyrogenic' environment

The environment in which a child exists in has the potential to result in a fire-related injury. This environment can be termed the 'pyrogenic' environment. This concept is not new and has been used by Swinburn *et al.* to describe the environment in relation to obesity as 'obesogenic", that is having the potential to result in obesity [96]. Understanding the 'pyrogenicity' of a child's environment aids in the prioritising of environmental elements for intervention at both a population and an individual level.

Traditional prevention approaches to child fire-related injury have focused on the child's immediate environment and the risks inherent to that environment. The concept of a child's 'pyrogenic' environment goes beyond the child's immediate environment, to identify more distal factors in the broader environment that may affect the 'pyrogenicity' of a child's environment. These distal factors might include socioeconomic environment, technological environment, housing policy, lifestyle, health policy, and fire policy.

Identifying factors influencing the 'pyrogenic' environment is fundamental to exploring the effect of the environment on childhood fire-related injury.

7.2 Injury data sources

This section discusses potential modifications of the coronial and Fire Service data sources for injury prevention purposes.

It is acknowledged that the data sources discussed in this section were established for specific use by the respective agency. However, the following suggested modifications to these data sources would benefit future research into the causes and outcomes of fire-related injury.

7.2.1 Coronial data

The establishment of a national coronial system in New Zealand would have far reaching benefits for all injuries across all age groups, ensuring deaths are investigated in and information recorded about them in a systematic and useful manner. Coroner's recommendations are a relatively untapped source of potential injury prevention advocacy. The process of making informed prevention recommendations could be incorporated into a national coronial system.

Runyan *et al.* reported the presence of an intoxicated person in a dwelling increases the risk of a fire death by 7.5 times, compared to a dwelling with no intoxicated occupant [60]. It would be valuable to have authority to obtain the blood alcohol level of caregivers in charge of children killed by fire, to assess the role of alcohol in fatal residential fire injury among children.

Recommendation

13) The New Zealand Fire Service Commission is involved in any future consultative process to establish a national coronial system in New Zealand.

7.2.2 Fire service data

Improved identification of burn victims specifically name, age, sex, gender, and street address would be useful information to have more consistently recorded by the fire service. Not only would this information assist the fire service to analyse more about the demographic characteristics of victims of fire, it would also aid external researchers in the linking of data from other sources.

The recording of presence or absence of fire safety technology was inconsistently recorded in fire service incident reports. The NSFS should mandate entry into fields relating to: absence/presence of smoke alarms, fire extinguishers, and sprinkler systems; absence/presence of smoking materials. In addition fire service staff completing incident reports should be encouraged to make an entry of 'unknown' or 'not applicable' into fields where information is unknown or not available.

The establishment by the New Zealand Fire Service of an ongoing analysis system to monitor fire-injury and fatality rates in New Zealand using modern principles of epidemiology would aid in the development of targeted fire-injury prevention strategies.

Recommendation

14) The New Zealand Fire Service Commission improves the consistency and quality of Fire Service data collected to improve the accuracy and usefulness of the data for injury prevention purposes. Specifically mandating the recording of the following: personal details of victims injured or killed in a fire eg. name, age, gender, street address; absence/presence of fire safety technology eg. smoke alarms, sprinkler systems; and absence/presence of smoking materials.

15) The New Zealand Fire Service Commission establishes an ongoing analysis system of fire incidents resulting in injury or death, combining routinely collected fire service data with population data, incorporating modern epidemiological tools including GIS mapping.

7.3 Future research

This section proposes two areas for future research.

7.3.1 Case-control study

Childhood fire-related injury resulting in death or hospitalisation is a relatively rare event. In view of this, it is worth considering the case-control methodology for future research into the modifiable risk factors for fire-related injury. Case-control studies are useful for quantifying the size of the relative and attributable risks related to risk factors of interest, in rare diseases [97, 98]. Important considerations in the design of case-control studies are the definition of the study base, case and control selection, and the measurement of exposures [99].

A source of cases might be children admitted to hospital for fire-related injury, and children dying as a result of fire-related injury. Controls would be ideally randomly selected from the community. Sources of information relevant to the study could include primary caregiver surveys, and environmental surveys relating to injury locations. Variables or exposures of interest to be examined in the case-control study may possibly include a number of those identified in the current literature review and descriptive study. Some exposures worth considering might include : socioeconomic factors eg. household income; housing factors eg. levels of overcrowding, tenure of property; access to resources factors eg. presence of telephone, access to transport; maternal factors eg. age, educational attainment; and home environment factors eg. smoker resident in the home, storage of petrol.

7.3.2 Non-fatal outcomes study

Findings from the literature review indicate the need for research into non-fatal outcomes following burn injury in children. And an evaluation of interventions designed to reduce the impact of these injuries. Methodological design suited to this type of research would be a longitudinal observational study. Subjects could be children who

survive fire-related injury requiring admission to hospital. The time period of observation would ideally continue into late adolescence and early adulthood. Outcomes to be assessed could be derived from the domains of physical, psychological, and emotional well-being. Measures used to determine outcomes of burn injury might include : developmental scales to assess a child's developmental status; functional scales to assess a child's level of independence to complete self-care activities; a scar assessment tool to rate a child's level of scarring; and diagnostic interviews to assess psychiatric outcomes.

Recommendation

16) The New Zealand Fire Service Commission gives consideration to future research into fire-related injury among children. Two studies proposed are:

i) A case-control study to identify potentially modifiable risk factors for fire-related childhood injury

ii) A study to evaluate the short and long term effects of non-fatal fire-related childhood injury, and the interventions designed to reduce the impact of these injuries.

8 CONCLUSION

Progress in the management of major burn injuries has resulted in a decrease in burn mortality. In spite of this fire-related injury remains a significant cause of childhood injury morbidity and mortality both internationally and in New Zealand. The prevention of burns from house fires, and children playing unsupervised with matches is a prevention focus for the Safekids 1995 strategic prevention plan *Keeping Kids Safe- In the Home, on The Road, at Play* [100].

Numerous studies have described the epidemiology of fatal and nonfatal childhood burn injury [2-18], but few have examined the epidemiology of fire-related injury [19-21].

The aim of this study was to review and summarise the literature on fire-related childhood injury in developed countries, and to provide an overview of unintentional fire-related injury among children aged 0 -14 years in the Auckland region during a 10-year period as a basis for the development of childhood injury prevention initiatives. This was achieved by conducting a literature review, and a descriptive study of fire-related injury resulting in hospitalisation or death among Auckland children during 1989-1998.

A review of the published literature revealed a paucity of information on fire-related injury among children resulting in hospitalisation. Results of the literature review indicated young children are most at risk of dying from fire injury, and being hospitalised as a result of fire-related injury. Males are more likely to be killed or injured than females. Ethnic minorities and socially and economically disadvantaged groups are over represented in fire-related injury fatality and hospitalisation statistics.

House fires are the major cause of fire-related fatalities. The use of flammable substances by adolescents accounts for a high proportion of hospitalisations in this age group. Risk factors specific for fire-related childhood injury identified in the literature include absence of a functioning smoke alarm, presence of a cigarette smoke in the household, child's clothing style (loose, flammable fabrics), maternal factors (age < 20 years, low educational attainment, more than two children), and low socioeconomic status.

Prevention strategies specific to fire-related childhood injury identified in the literature were discussed in the review in the categories of educational, environmental, and legislative. Educational prevention interventions targeting fire-related injury have had varying levels of success with few demonstrated reductions in injury rates. Future educational interventions require analytical trials to evaluate their effectiveness. In contrast environmental prevention *passive* interventions have demonstrated some reductions in injury rates, for example the introduction of flame-retardant sleepwear, and automatic sprinkler systems. Legislation and regulation if enforced, have a major role in supporting prevention interventions, although the benefits to those socially disadvantaged may be less effective. Findings from the review of prevention strategies for fire-related injury pointed to the need for coordinated intersectoral prevention efforts that combine targeted educational, environmental, and legislative interventions at all levels of society. In addition the need for analytical evaluation of the effectiveness of fire injury prevention efforts is highlighted.

The descriptive study was a retrospective population-based study, of all children (0-14 years), hospitalised (primary admission only) or died as a result of unintentional fire-related injury occurring in the Auckland region during a 10-year period (1989-1998). Fatality cases were identified from NZHIS mortality data, forensic pathology files, and fire service records. Information relating to exposures of interest was abstracted from forensic pathology files, NZFS fatal incident reports, and coronial records. Hospitalisation cases were identified from NZHIS morbidity datasets, and Middlemore and Starship hospital casemix reports. Relevant exposure information was abstracted from hospital records and New Zealand Fire Service records where applicable.

The study identified the following population groups were at increased risk of fire-related death or injury requiring hospitalisation: younger children (0 – 4 years), males, ethnic minorities, and the socioeconomically disadvantaged. These findings are consistent with previous research in New Zealand and overseas. There appears to be an excess risk of fire-related death among Pacific Islands children, and an excess risk of hospitalisation among Maori children. Increased risks among these groups may in part reflect their over representation in the proportion of people living in disadvantaged circumstances.

Consistent with the published literature was the finding in this study that the home environment (including yard, outbuildings, and driveway) was the most common place of fire-related injury resulting in death or hospitalisation. In this study, as with the international literature, house fire deaths remain the biggest cause of fire fatalities in children. Fires in parked cars were responsible for a quarter of fire deaths in this study. This mechanism is not reported as a significant cause of injury in international studies. Ignition of clothing contributed to a large portion of the morbidity associated with fire-related injury among children in this study, despite the reduction in overall injuries from this cause seen worldwide. While relatively few house fires in this study were related to the careless disposal of smoking material, there was a high proportion of both fatal and non fatal cases resulting from children playing with matches or lighters.

Linking findings from the descriptive study to the literature review developed implications for fire-related childhood injury. Implications for prevention included the need for: continued educational efforts regarding the storage and dangers of playing with, matches or lighters; the inappropriateness of cars as play areas for children; investigation of ways to reduce adolescent petrol related injuries; feasibility of flame retardant clothing for children; legislation to mandate hard-wiring of smoke alarms in new homes and Housing New Zealand Limited dwellings; encouraging insurance companies to offer rebates for homes with fire safe technology. Technological implications identified included maintenance issues with battery operated smoke alarms, and reducing costs associated with hard-wired alarms and residential sprinkler systems.

The concept of a ‘pyrogenic’ environment (that is one that supports a fire-related injury occurrence) was developed using the findings from the literature review. Further exploration and development of the ‘pyrogenic’ environment concept is identified as a potential component of future fire prevention initiatives.

Modifications to increase the accuracy and usefulness of fire-related injury data sources for injury prevention purposes were discussed, specifically coronial, and Fire Service

data. And recommendations for the development of ongoing epidemiological analysis of fire injury and fatality data was recommended.

Implications for future research were discussed and two studies proposed. A case-control study to identify potentially modifiable risk factors for fire-related childhood injury. And a non-fatal outcomes study, to evaluate the short and long term effects of fire-related childhood injury and to evaluate the interventions designed to reduce the impact of these injuries.

In summary childhood fire-related injuries are an important public health issue for New Zealand children. This study has highlighted the findings from the international and New Zealand literature regarding the magnitude of fire-related childhood injury. And has drawn on findings from the descriptive study to provide some insights into the epidemiology of fire-related childhood injury. The findings indicate the need for analytical research to assist in the development and implementation of interventions to reduce the mortality and morbidity associated with unintentional fire-related injury among children.

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