Opportunities to prevent fatalities due to injury: a cross-sectional comparison of prehospital and in-hospital fatal injury deaths in New Zealand

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Abstract

Objective: There is interest in opportunities that lie in the prehospital setting to reduce the substantial burden of fatal injury. This study examines the epidemiology of prehospital and in-hospital fatal injury in New Zealand.

Methods: All deaths registered in 2008–2012 with an underlying cause of death external cause-code V01-Y36 (ICD-10-AM) were identified. The setting of death was determined following linkage to, and review of, hospital discharge data and Coronial records.

Results: Of 7,522 injury deaths, 80% occurred in a prehospital setting, with the highest burden relating to males. Within those fatally injured, 25–54-year-olds had a higher risk of prehospital death than 55–84-year-olds (adjusted Relative Risk [aRR] 1.20, 95%CI 1.16, 1.20). Similarly, those injured due to drowning (aRR 1.39, CI 1.26, 1.53) and non-hanging suffocation (aRR 1.31, CI 1.18, 1.45) had a higher risk of prehospital death than those 'struck by/machinery'.

Conclusion: Prehospital deaths account for four out of five fatal injuries in New Zealand. Of the fatally injured population, the probability of prehospital death differed by age, sex, injury mechanism and intent.

Implications for public health: This study highlights the importance of strengthening prevention efforts to reduce the substantive burden of prehospital fatalities in New Zealand.

Key words: prehospital, in-hospital, mortality, epidemiology, injury

Injury has a significant impact on society globally with an estimated 4.8 million deaths and 913 million healthcare interactions due to injury in 2013.[1] In New Zealand, injury is the leading cause of death and disability in those aged 1 to 44 years old, imposing significant personal and economic costs estimated in 2010 at $NZ 6.2 million per fatality.[2,3] Reducing fatal injury requires multi-dimensional approaches that cover both primary and secondary prevention efforts. Secondary prevention efforts, responding to limit the impact or severity of injury and delivered as part of an optimised trauma system, can improve the chances of survival following injury for individuals and reduce the impact of injury on society.[4] Recent reviews of New Zealand's trauma system highlight that the current system is fragmented and under-resourced; as such, the performance of the system falls behind other comparative countries, such as Australia.[5]

As public health and trauma systems mature, there is increasing interest in the opportunities that lie prior to hospital admission to reduce the occurrence of injury through public health-focused primary preventions and to improve survival from injury through secondary prevention actions. Internationally, there has been increased research interest in the prehospital setting due to an observed shift in the relative temporal distribution of injury deaths towards the occurrence of death in this setting.[6-11] Reasons for this shift could, in part, be attributed to improved trauma system care, changes in injury mechanisms and injury severity, and ageing populations.[6] Prehospital death is defined as a death occurring on scene or during transfer to hospital. Prehospital deaths are more likely to involve males and result from intentional self-harm or transport incidents.[7-11] The few previous comparisons of pre- and in-hospital deaths indicate there are important differences in the causes and circumstance of fatal injury on the basis of setting of death.[1-3]

Previous examinations of prehospital injury deaths, although limited to regional studies, secondary prevention and trauma cases,[12-15] indicate there are opportunities to prevent injury and improve survivability following serious life-threatening injury. It is important therefore to understand the burden and patterns of prehospital fatal injuries on a national level to identify opportunities for prevention. This paper examines socio-demographic, socio-geographical and injury patterns of prehospital and in-hospital fatal injury in New Zealand in order to determine their incidence and to explore predictors of prehospital death.

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Methods

The data sources used for sample section and prehospital case ascertainment included New Zealand's Mortality Collection (MC) that captures cause of death for all deaths registered in New Zealand and hospital discharge information (National Minimum Dataset – NMDS).[4] From New Zealand's MC, all injury deaths for those aged 0–84 years of age, registered during the period 2008–2012, were identified using underlying cause of death external cause codes (E-codes) in the International Classification of Diseases (ICD-10-AM) range V01-Y36.[16] In-hospital deaths occurred during the initial hospital admission. In-hospital deaths were identified as those MC cases that deterministically linked using unique National Health Index (NHI) numbers to the NMDS with: 1) a final hospital discharge status of 'death'; or 2) 'hospital' recorded as the address at which death occurred; or 3) date of hospital discharge identical to the date of death.

The primary source of data on age, sex, ethnicity and mechanism of injury was the MC. Age was grouped into three broad age categories of 0–24, 25–54 and 55–84 years of age that reflect the broadly similar patterns of injury within each group. Four categories of prioritised ethnicity were created in the following order: Indigenous Māori, Pacific, Asian, and European grouped with all other specified ethnic groups, i.e. not including missing/unknown ethnicity.[17] Mechanism of injury, incident location and injury intent were coded using the ICD-10-AM groupings. There were insufficient data available to include injury severity for this sample (available in only 1,796 cases).

'Trauma region' categorised New Zealand's 20 District Health Boards into four regions of trauma management, each with different levels of trauma service resourcing and capacity.[5] The four regions are Northern (Northland, Auckland, Waitemata, Counties Manukau), Midland (Tairawhiti, Taranaki, Lakes, Waikato, Bay of Plenty), Central (Capital and Coast, Hutt, Wairarapa, Mid Central, Hawke Bay, Whanganui), and South Island (Nelson- Marlborough, West Coast, Canterbury, South Canterbury, Southern). A fifth category included areas not elsewhere classified such as off-shore areas, islands and international visitors.

To obtain key variables describing the location of the injury incident, the sample identified from the MC was matched to Coronial records held by the National Coronial Information System using probabilistic matching of personal details.[4] Socio-geographical (i.e. social phenomena expressed in geographical location) characteristics included small area-level deprivation and urbanity of incident. Small area geographical meshblocks were coded from the physical address of the injury incident occurrence obtained from matched Coronial records. Small area-level deprivation was then derived using the 2013 New Zealand Deprivation Index (NZDep), with deciles categorised into quintiles where '1–2' represent the least and '9–10' the most deprived meshblocks.[18] Urbanity of incident was derived using Statistics New Zealand urban area classifications assigned to meshblocks: main urban area (population ≥30,000 people); secondary urban area (10,000–29,999 people); minor urban area (1,000–9,999 people); rural centre (300–999 people); and other rural, which included all remaining meshblocks.[19]

The frequency, percentage and incidence of prehospital injury deaths were calculated and compared with in-hospital injury deaths. Denominators for the overall population and age, sex and ethnicity sub-populations were calculated using the census-estimated resident population obtained from Statistics New Zealand. Exact Poisson confidence intervals were calculated for all incidence rates. Deaths that occurred during catastrophic events, defined as more than 10 deaths in an incident, were excluded from the analyses.

Regression methods were used to examine the socio-demographic, injury and socio-geographic predictors of injury death in the prehospital setting, compared to deaths in the in-hospital setting. Unadjusted and adjusted univariable models were created using modified Poisson regression with robust error variance to estimate relative risks.[20] Two levels of adjustment were examined: the first included age, sex and ethnicity, while the second additionally included the year of death, mechanism of injury and intent of injury. Reference categories were selected on the basis of having the highest proportion of prehospital deaths for comparison. Missing values were included as a separate category for all variables included in modelling.

Data analyses were performed using STATA (version 13.0 SE, StataCorp, College Station, TX).

Results

Of the 9,430 injury deaths occurring during the 2008–2012 period, 79.8% (n=7,522) involved people aged 0–84 years. Of these, four in five injury deaths occurred in a prehospital setting (n=6,016, 79.9%), equating to around 1,200 injury deaths annually. The average annualised rate of prehospital fatal injury (28.2/100,000 person-years; 95%CI 27.5, 28.9) was four times the in-hospital fatality rate (7.1/100,000; 95%CI 6.7, 7.4).

Socio-demographic differences

For all socio-demographic characteristics examined, the number and rate of prehospital injury fatalities exceeded those for in-hospital deaths (Table 1). Prehospital fatalities were most common in those aged 25–54 years, males, those of European ethnicity and those residing in the Northern North Island trauma-care region. Likewise, the rates of prehospital fatal injury were also highest among 25–54-year-olds and males. However, the rates were highest for Māori and those residing in the Central North Island trauma-care region.

The majority of the in-hospital injury deaths were among those aged 55–84 years, with the in-hospital mortality rate among this age group being approximately five times higher than for other age groups. The differences in rates for in-hospital injury deaths were less stark by sex, ethnicity and trauma-care region. For example, the rate of prehospital fatal injury for Māori (41.4/100,000 persons, 95%CI 39.2, 43.7) was one-and-a-half times greater than the rate for those of European ethnicity (27.4/100,000 person-years, 95%CI 26.5, 28.2); whereas, for in-hospital fatalities the rates for both groups were comparable (Māori 7.5/100,000 person-years, 95%CI 6.6, 8.5; European 7.6/100,000 person-years, 95%CI 7.2, 8.1).

Comparisons of proportional differences of pre- and in-hospital deaths identify that the greatest differences are observed for 25–54-year-olds (90% of deaths prehospital), females (83%), Pacific (85%), and those residing in the South Island (83%) or 'other areas' (82%), generally off-shore islands. The 25–54-year-old age group had the highest ratio of prehospital deaths with nine per in-hospital deaths, while 55–84-year-olds have the lowest ratio (1.6:1), reflecting the larger relative contribution of in-hospital deaths in this age group.

Injury differences

The majority of in-hospital injury deaths were due to unintentional injuries (82.8%, n=1,247) compared to more than half (55.9%, n=3,367) of prehospital injury deaths (Table 2). In contrast, the vast majority of deaths occurred in the prehospital setting for self-inflicted injuries (92.9%, n=2,344) and injuries of undetermined intent (93.1%, n=81). This pattern was further reflected in the ratio of pre- to in-hospital injury deaths where there were more than 13 prehospital deaths for every in-hospital death for those with self-inflicted or indeterminate injury intents.

The most common mechanisms of prehospital fatal injury were transport and suffocation followed by poisonings (Table 2). In contrast, in-hospital fatal injury was predominantly as a result of falls with a ratio of 0.6 prehospital deaths for every in-hospital death. The largest proportion of prehospital deaths was observed for drownings (96.5%, n=329), with a ratio of 27 prehospital deaths for every in-hospital death. Other mechanisms of injury with more than 90% of deaths occurring in the prehospital setting included injuries due to firearms (91.7%, n=243, mainly self-inflicted n=196), poisoning (90.7%, n=999) and suffocation (93.4%, n=1,709, mainly due to hangings n=1,361). There were no obvious differences by year of death registration.

Socio-geographic differences

The home setting was the most prevalent location of the injury incident followed by transport areas, regardless of the location of death (Table 2). Unsurprisingly, those with injuries sustained in medical service areas (such as in a hospital) and residential aged care settings had the lowest ratios of prehospital deaths, with 0.3 and 0.7 prehospital deaths for every in-hospital death, respectively. The highest proportion and ratio of prehospital deaths occurred in the rural farm, country and forest setting, with 20 prehospital deaths for every in-hospital death.

Where the incident location was able to be geocoded from injury address recorded in linked Coronial files (n=6,330, missing for 42% of in-hospital and 9% of prehospital deaths), the majority of both pre- and in-hospital injury deaths occurred in main urban areas. However, one-third of prehospital injury deaths occurred in 'other rural areas', such as areas outside of rural service centres. More than 90% of the injury deaths that happened in rural centres occurred prehospital, resulting in a pre- to in-hospital death ratio of 15:1, three times the ratio for main urban centres. There was little difference in the proportion of prehospital injury deaths by the level of deprivation at the location of the injury incident as measured by NZDep.

Predictors of prehospital injury deaths

Unadjusted analyses, presented in Table 3, identified groups at increased risk of prehospital death. Adjusting all models by age, sex and ethnicity increased the estimated risk of prehospital death for injuries due to fire and transport causes and for those sustained at home. Risk estimates for injuries sustained in recreation, cultural and sports settings and injuries sustained in residential aged care were attenuated. Of interest was the similarity in the adjusted relative risk (aRR) for deaths due to intentional self-harm (aRR 1.19, 95%CI 1.17, 1.22) and cases where the injuries sustained were of an indeterminate intent (aRR 1.21, 95%CI 1.14, 1.28). The highest risk of prehospital death following injury by mechanism occurred for drowning cases (aRR 1.48, 95%CI 1.34, 1.63). Those aged 0–24 (aRR 1.38, 95%CI 1.33, 1.44) and 25–54 years (aRR 1.45, 95%CI 1.40, 1.50) had a higher risk of prehospital death following injury. When compared with the Midland trauma care region, those injured in

Table 1: Table of comparison of socio-demographic characteristics of pre- and in-hospital deaths, New Zealand, 2008-2012.

	Total (n=7,522)	Prehospital deaths (n=6,016)		In-hospital deaths (n=1,506)		Comparison	
	N	N (col %)	Rate (95% CI)[b]	N (col %)	Rate (95% CI)[b]	Per cent Prehospital	Ratio pre : in-hospital
Age (years)							
0-24	1,872	1,606 (26.7)	21.1 (20.1, 22.2)	266 (17.7)	3.5 (3.1, 3.9)	85.8	6.0
25-54	3,259	2,936 (48.8)	33.1 (31.9, 34.4)	323 (24.5)	3.6 (3.3, 4.1)	90.1	9.1
55-84	2,391	1,474 (24.5)	30.1 (28.6, 31.7)	917 (60.9)	18.7 (17.5, 19.9)	61.7	1.6
Sex							
Male	5,277	4,367 (72.6)	41.4 (39.9, 42.4)	910 (60.4)	8.6 (8.0, 9.2)	73.5	4.8
Female	2,245	1,649 (27.6)	14.9 (14.2, 15.6)	596 (39.6)	5.4 (4.9, 5.8)	82.8	2.8
Ethnicity[a]							
Māori	1,628	1,377 (22.9)	41.4 (39.2,43.7)	251 (16.7)	7.5 (6.6, 8.5)	78.2	5.5
Pacific	376	311 (5.2)	22.7 (20.3, 25.4)	65 (4.3)	4.7 (3.7, 6.1)	84.6	4.8
Asian	366	297 (4.9)	12.9 (11.5, 14.5)	69 (4.6)	3.0 (2.3, 3.8)	82.7	4.3
NZ European & other	5,152	4,031 (67.0)	27.4 (26.6, 28.3)	1,121 (74.4)	7.6 (7.2, 8.1)	78.2	3.6
Trauma Region							
Northern North Island	2,256	1,777 (29.5)	22.0 (20.9, 25.4)	479 (31.8)	5.9 (5.4, 6.5)	78.8	3.7
Central North Island	1,701	1,363 (22.7)	32.6 (30.9, 34.4)	338 (22.4)	8.1 (7.2, 8.9)	80.1	4.0
Midland North Island	1,547	1,207 (20.1)	28.2 (26.6, 29.8)	340 (22.6)	7.9 (7.1, 8.8)	78.0	3.6
South Island	1,825	1,510 (25.1)	29.3 (27.9, 30.8)	315 (20.9)	6.1 (5.5, 6.8)	82.7	4.8
Other areas	193	159 (2.6)	N/A[c]	34 (2.3)	N/A[c]	82.4	4.7

Notes:
a: prioritised ethnicity
b: per 100,000 person years
c: denominator not available
col % = column percent, 95% CI = 95% Confidence Interval, NZ=New Zealand.

Table 2: Comparison of injury and socio-geographical characteristics of pre- and in-hospital injury deaths, New Zealand, 2008–2012.

	Total (n=7,522)	Prehospital deaths (n=6,016)	In-hospital deaths (n=1,506)	Comparison	
	N	N (col %)	N (col %)	Per cent Prehospital	Ratio pre : in-hospital
Mechanism of injury (ICD-10)	154	138 (2.3)	16 (1.1)	89.6	8.6
Cut/piercing	341	329 (5.5)	12 (0.8)	96.5	27.4
Drowning	1,139	445 (7.4)	694 (46.1)	39.1	0.6
Fall	120	90 (1.5)	30 (1.9)	75.0	3.0
Fire/Hot object	265	243 (4.0)	22 (1.5)	91.7	11.0
Firearms	71	61 (1.0)	10 (0.7)	85.9	6.0
Natural/Environmental	206	161 (2.7)	45 (3.0)	78.2	3.7
Other/Unspecified	1,101	999 (16.6)	102 (6.8)	90.7	9.8
Poison	203	135 (2.2)	68 (4.5)	66.5	1.9
Struck by/Machinery	386	248 (5.8)	38 (2.5)	90.2	6.5
Suffocation - other	1,444	1,361 (22.6)	83 (5.5)	94.3	16.3
Suffocation - hanging	2,092	1,706 (28.4)	386 (25.6)	81.6	4.4
Transport					
Intent of injury					
Unintentional	4,609	3,362 (55.9)	1,247 (82.8)	72.9	2.7
Self-inflicted	2,521	2,344 (38.9)	177(11.8)	92.9	13.2
Assault/Legal intervention	305	229 (3.8)	76 (5.0)	75.1	3.0
Undetermined	87	81 (1.4)	6 (0.4)	93.1	13.5
Year of death registration					
2008	1,556	1,244 (20.7)	312 (20.7)	79.9	3.9
2009	1,564	1,260 (20.9)	304 (20.2)	80.6	4.1
2010	1,519	1,206 (20.1)	313 (20.8)	79.4	3.9
2011	1,425	1,113 (18.5)	312 (20.7)	78.1	3.6
2012	1,458	1,193 (19.8)	265 (17.6)	81.8	4.5
Incident location					
Commercial, industrial	208	166 (2.8)	42 (2.8)	79.8	3.9
Farm, country, forest[a]	689	656 (10.9)	33 (2.8)	95.2	19.9
Recreation, cultural, sports	195	168 (2.8)	27 (1.8)	86.2	6.2
Education, residential institute	68	54 (0.9)	14 (0.9)	79.4	3.9
Transport locations	1,965	1,588 (26.4)	377 (25)	80.8	4.2
Home	3,368	2,729 (45.4)	639 (42.4)	81.0	4.3
Medical service areas	58	12 (0.2)	46 (3.1)	20.7	0.3
Residential aged care	276	115 (1.9)	161 (10.7)	41.7	0.7
Other & unknown	210	188 (3.1)	22 (1.5)	89.5	8.5
Missing/unknown	485	340 (5.7)	145 (9.6)		
Urbanity (incident location)					
Main urban	3,473	2,895 (48.1)	578 (38.4)	83.4	5.0
Minor urban	429	383 (6.4)	46 (3.1)	89.3	8.3
Secondary urban	304	263 (4.4)	41 (2.7)	86.5	6.4
Rural Centre	166	156 (2.6)	10 (0.7)	93.9	15.6
Other rural area	1,958	1,764 (29.3)	194 (12.9)	90.1	9.1
Missing	1,192	555 (9.2)	637 (42.3)		
NZDep index (incident location)					
1-2 (low)	899	782 (13.0)	117 (7.8)	86.9	6.7
3-4	1,207	1,066 (17.7)	141 (9.4)	88.3	7.5
5-6	1,374	1,171 (19.5)	203 (13.5)	85.2	5.8
7-8	1,365	1,180 (19.6)	185 (12.3)	86.5	6.4
9-10 (high)	1,455	1,235 (20.5)	220 (14.6)	84.9	5.6
Missing	1,222	582 (9.7)	640 (42.5)		

Notes:

a: includes areas of farmland, water, forest and mountains

col% = column percent.

the Southern region had a slightly elevated risk of prehospital death (aRR 1.04, 95%CI 1.01, 1.07). There was no increase in the risk of prehospital death observed by ethnicity, year of death, or area level deprivation for the location of the injury incident.

Further adjustment by year of death, mechanism of injury and intent of injury, overall, made minimal difference. A number of estimates of risk obtained from model 1 were attenuated towards those obtained from the univariate analyses. The major exception was observed for age where the strongest attenuation was observed suggesting much of the risk by age is explained by mechanism and intent of injury. Ethnicity was explored further with the additional adjustment of rurality and injury mechanism; however, these variables shifted the risk estimates back towards the unadjusted value (aRR 0.97, 95%CI 0.93, 1.04).

Discussion

This study examined and compared the incidence and characteristics of pre- and in-hospital injury deaths on a national basis in New Zealand. Prehospital fatalities made a major contribution to injury deaths with four out of five injury deaths occurring either at the scene or prior to receiving hospital-level care. Leading causes of prehospital fatalities include unintentional transport-related injuries and intentional suffocation by hanging, as well as injuries occurring at home or in transport settings. The leading cause of in-hospital injury deaths is falls that occur in the community, predominantly among older adults.

To the best of our knowledge, predictors of prehospital injury death, compared to in-hospital injury deaths in New Zealand, have not previously been examined. Within the fatally injured population, the predictors of increased risk of prehospital injury generally reflected the dominant patterns of prehospital injury deaths. Significantly, an increased risk was found for young and middle-aged, males, a range of injury mechanisms including drownings, firearms and poisonings, geographical locations outside the main urban areas, and injuries that were self-inflicted or of undetermined intent. Those at increased risk of in-hospital death included those fatally injured during a fall, due to injuries sustained in medical service areas, or in an unknown location. These findings generally reflect falls in

older adults (75–84 years) where there are uncertainties about where the fall occurred.

Few national studies have described patterns of fatal injury by geographic location of death in relation to hospital services. In contrast to this study that found 80% of injury deaths occurred prehospital, a Scottish study identified 36% of trauma deaths in 2000–2011 occurred in the prehospital setting.[21] The difference is, in part, likely to be explained by the exclusion of intentional and non-traumatic injuries in the Scottish study. In addition, Emergency Medical Services (EMS) coverage within one hour across Scotland is 94%, compared with 84% in New Zealand.[21,22] However, studies including intentional injuries typically report higher overall proportions of prehospital injury deaths, similar to New Zealand: 90% of deaths occurred in a prehospital setting in Sweden, while 71% of deaths occurred out-of-hospital in a population of trauma registry patients in Victoria, Australia.[8,15] Although the main profile of pre- and in-hospital deaths for both Sweden and Victoria was similar to those observed in New Zealand, a few differences were observed. Half of all prehospital deaths in Victoria, Australia, were due to self-inflicted injuries. Self-inflicted injuries were not as dominant in our study, comprising 39% of prehospital deaths.[15] Poisonings were the third most common cause of prehospital death in our findings, in contrast to Sweden, where they were the leading cause of prehospital death.[8] The Victorian study excluded poisonings.[15] Furthermore, transport injuries were not as dominant in Sweden with only 14% of prehospital deaths due to motor vehicle traffic injuries, compared to 28% in New Zealand.[8] This may be partly explained by the inclusion of deaths due to other forms of transport including motorbikes, cycles, air and watercraft in our data.

Our study examined patterns of prehospital deaths by ethnicity, a socio-demographic variable not considered in previous epidemiological studies of prehospital fatalities. The Waitangi Tribunal recently outlined the stark and persistent inequities in the burden of poor health and access to healthcare services experienced by Māori reinforcing the importance of examining ethnic differences in New Zealand prehospital injury deaths.[23] This study found Māori experienced a disproportionately high burden of prehospital deaths (22% despite contributing to 15% of the New Zealand

Table 3: Predictors of prehospital (compared to in hospital) fatal injury in fatally injured population.

Model	Characteristics	Univariate RR (95% CI)	Adjusted[a] aRR (95% CI)	Adjusted[b] aRR (95% CI)
1	**Age (years)**			
	0–24	**1.39 (1.34, 1.44)**	**1.38 (1.33, 1.44)**	**1.14 (1.10, 1.18)**
	25–54	**1.46 (1.41, 1.51)**	**1.45 (1.40, 1.50)**	**1.20 (1.16, 1.23)**
	55–84	Ref	Ref	Ref
2	**Sex**			
	Male	**1.13 (1.10,1.16)**	**1.08 (1.05, 1.11)**	**1.05 (1.02, 1.07)**
	Female	Ref	Ref	Ref
3	**Ethnicity (prioritised)**			
	Māori	0.96 (0.92, 1.01)	0.99 (0.95, 1.04)	0.99 (0.94, 1.03)
	Pacific	1.04 (0.98, 1.10)	0.99 (0.95, 1.05)	0.98 (0.94, 1.03)
	Asian	1.02 (0.95, 1.09)	0.98 (0.92, 1.05)	0.97 (0.92, 1.04)
	NZ European & Other	Ref	Ref	
4	**Mechanism of injury**			
	Cut/pierce	**1.34 (1.21, 1.51)**	**1.33 (1.20, 1.49)**	**1.31 (1.17, 1.46)**
	Drowning	**1.45 (1.31, 1.60)**	**1.48 (1.34, 1.63)**	**1.39 (1.26, 1.53)**
	Fall	**0.59 (0.52, 0.66)**	**0.73 (0.65, 0.83)**	**0.62 (0.55, 0.70)**
	Fire	1.13 (0.98, 1.30)	**1.19 (1.03, 1.37)**	1.08 (0.97, 1.25)
	Firearms	**1.38 (1.24, 1.53)**	**1.37 (1.23, 1.52)**	**1.25 (1.13, 1.39)**
	Natural/Environmental	**1.29 (1.13, 1.48)**	**1.36 (1.19, 1.54)**	**1.28 (1.12, 1.46)**
	Other/Unspecified	**1.18 (1.03, 1.34)**	**1.20 (1.06, 1.36)**	**1.14 (1.04, 1.29)**
	Poisoning	**1.36 (1.24, 1.51)**	**1.35 (1.23, 1.49)**	**1.25 (1.13, 1.39)**
	Suffocation - other	**1.40 (1.27, 1.55)**	**1.40 (1.27, 1.54)**	**1.31 (1.18, 1.45)**
	Suffocation - hanging	**1.23 (1.11, 1.35)**	**1.24 (1.13,1.37)**	**1.22 (1.17, 1.36)**
	Transport	1.17 (0.99, 1.38)	**1.27 (1.08, 1.48)**	**1.19 (1.08, 1.31)**
	Struck by/machinery	Ref	Ref	
5	**Incident location**			
	Commercial & industrial	0.99 (0.92, 1.06)	0.98 (0.91, 1.04)	0.92 (0.91, 1.04)
	Farm, country & forest[d]	**1.18 (1.15, 1.21)**	**1.15 (1.12, 1.19)**	**1.09 (1.05, 1.13)**
	Recreation & cultural	**1.07 (1.01, 1.13)**	1.02 (0.96, 1.08)	0.97 (0.92, 1.02)
	Education & residential	0.98 (0.87, 1.11)	0.94 (0.84, 1.07)	0.88 (0.81, 0.97)
	Home	1.00 (0.98, 1.03)	**1.04 (1.01, 1.07)**	0.94 (0.90, 0.98)
	Medical service area	**0.26 (0.15, 0.42)**	**0.28 (0.17, 0.45)**	0.27 (0.21, 0.34)
	Other	**1.10 (1.05, 1.17)**	**1.09 (1.03, 1.14)**	1.05 (0.99, 1.11)
	Transport	Ref	Ref	Ref
6	**Intent of injury**			
	Assault & legal	1.10 (0.96, 1.10)	0.96 (0.89, 1.02)	0.91 (0.84, 0.98)
	Self-inflicted	**1.27 (1.25, 1.30)**	**1.19 (1.17, 1.22)**	**1.09 (1.06, 1.13)**
	Undetermined	**1.27 (1.20, 1.36)**	**1.21 (1.14, 1.28)**	**1.14 (1.06, 1.22)**
	Unintentional	Ref	Ref	Ref
7	**Trauma Region[c]**			
	Northern North Island	0.98 (0.95, 1.01)	0.98 (0.96, 1.02)	0.99 (0.96, 1.09)
	Central North Island	0.97 (0.94, 1.01)	0.98 (0.95, 1.02)	0.99 (0.96, 1.02)
	South Island	**1.03 (1.00, 1.07)**	**1.04 (1.01, 1.07)**	**1.03 (1.00, 1.06)**
	Other areas	1.03 (0.96, 1.10)	1.03 (0.96, 1.10)	**1.07 (1.00, 1.15)**
	Midland North Island	Ref	Ref	Ref
8	**Urbanity[c]**			
	Minor urban	**1.07 (1.03, 1.11)**	**1.07 (1.04, 1.11)**	**1.05 (1.02, 1.09)**
	Other rural	**1.08 (1.06, 1.10)**	**1.07 (1.06, 1.10)**	**1.12 (1.09, 1.14)**
	Rural Centre	**1.13 (1.08, 1.17)**	**1.04 (1.01, 1.07)**	**1.14 (1.09, 1.19)**
	Secondary urban	1.03 (0.99, 1.09)	1.03 (0.96, 1.08)	**1.07 (1.00, 1.15)**
	Main urban	Ref	Ref	Ref

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Table 3 cont.: Predictors of prehospital (compared to in hospital) fatal injury in fatally injured population.

Model	Characteristics	Univariate RR (95% CI)	Adjusted[a] aRR (95% CI)	Adjusted[b] aRR (95% CI)
9	**NZDep[c]**			
	9-10 (high)	0.98 (0.94, 1.01)	1.03 (0.99, 1.06)	0.96 (0.93, 0.99)
	7-8	0.99 (0.96, 1.03)	0.99 (0.95, 1.02)	0.98 (0.95, 1.01)
	5-6	0.97 (0.95, 1.01)	1.00 (0.97, 1.03)	0.98 (0.95, 1.01)
	3-4	1.01 (0.98, 1.04)	0.99 (0.97, 1.03)	1.00 (0.97, 1.04)
	1-2 (low)	Ref	Ref	Ref
10	**Year of death**			
	2012	1.02 (0.99, 1.06)	0.97 (0.94, 1.01)	1.02 (0.99, 1.05)
	2011	0.98 (0.94, 1.01)	0.99 (0.96, 1.02)	0.98 (0.95, 1.01)
	2010	0.99 (0.96, 1.03)	0.98 (0.95, 1.01)	0.99 (0.96, 1.02)
	2009	1.00 (0.97, 1.04)	1.01 (0.98,1.05)	1.00 (0.97, 1.03)
	2008	Ref	Ref	Ref

Notes:
a: adjusted for age, sex & ethnicity
b: adjusted for age, sex, ethnicity, intent of injury, mechanism of injury, year of death
c: Number of observations 6,300
d: includes areas of farmland, water, forest and mountains
RR=relative risk, aRR= adjusted relative risk, 95% CI = 95% Confidence Interval, Ref = reference.

population) as well as the highest rate of prehospital mortality of all the ethnic sub-groups examined. However, the relative risks (unadjusted and adjusted) of death occurring in the prehospital setting for Māori were similar when compared with those of European ethnicity. Our previous work has demonstrated disparities in timely access to EMS for Māori in New Zealand, in part reflecting the rural locale of many Māori communities.[24]

Rural areas typically have higher rates of fatal injury when compared to urban areas. The reasons for this excess are often attributed to delayed identification of injuries, increased distances to help and care, longer EMS response times, delayed surgical care, and fewer front-line personnel trained in advanced life support techniques for rural communities.[25] Regional trauma care service areas were also considered in this study, with each region operating with different levels of trauma service resourcing and capacity.[5] The South Island trauma region, when compared to the Midland North Island trauma region (the first region to fully establish an advanced trauma system), had a significantly increased risk of prehospital injury death. Our recent geospatial analysis of timely access to EMS and advanced-level healthcare across New Zealand indicates its challenging geography, results in dispersed medical services and access to EMS.[26] Geographically marginalised groups, including Māori and people living in less populated areas such as the South Island, have lower levels of timely access to advanced-level hospital care, which may partly explain these socio-geographical relationships.[26] Future research should examine reasons for these socio-geographical inequalities to understand the public health implications of this difference and to inform actions to address the higher risk of prehospital mortality for geographically marginalised communities.

Public health opportunities to address New Zealand's substantial prehospital fatal injury burden are varied. While primary prevention is important for all injuries, this is especially relevant for injury mechanisms with a high probability of prehospital death, such as drowning, firearm, and intentional injuries. In these areas, strengthened primary prevention actions are needed, including interventions focused on suicide prevention – given the preponderance of intentional fatalities in the prehospital setting. The injuries that result from these mechanisms are amenable to secondary prevention actions such as bystander intervention, but by their very nature, require this activity to occur in the period immediately following injury, which may not always be possible due to the events occurring in remote or intentionally isolated locations (in the case of suicide). The extension of hospital-based trauma systems into improved integrated equitable prehospital care would extend the benefits of secondary prevention for those with initially survivable trauma-related injuries.[27] Our previous analysis of a sub-group of this cohort suggests there is also a potential window of opportunity for bystander interventions, such as rapid delivery of appropriate first aid that may save lives.[28]

This study uses rich national mortality and morbidity data from routine health data collections and Coronial records to examine pre- and in-hospital patterns of fatal injury, improving on the generalisability of previous New Zealand work focused on regional trauma populations only.[12,14] As few studies examine predictors of prehospital injury beyond the distribution of deaths, our study is the first we are aware of that estimates the risk of death in the prehospital setting. It is a limitation, however, that the sample does not include those who survived their injuries, and generalisability of these predictors is therefore limited to the fatal injury population only. A further limitation of this study is that we have been unable to assign injury severity scores due to a lack of post-mortem reports for the whole cohort. A previous analysis has examined this for the 1,796 deaths with post-mortem reports.[28] Large amounts of missing data (due to lack of meshblock data) for the urbanity and NZDep measures may bias estimates of risk for these variables. This study describes the period 2008–2012; substantial delays in the closing of Coronial case files limit the currency of these data. These data are limited in their ability to inform secondary prevention efforts. A future New Zealand study using other sources of data focused on the delivery of emergency care is underway; this will build upon the current study by identifying potentially modifiable factors for secondary prevention.

Conclusions and public health implications

In conclusion, we found prehospital deaths account for four out of five fatal injuries in New Zealand. In the fatally injured population, the probability of dying in a prehospital setting compared to in-hospital differed by age, sex, injury mechanism and intent. These findings identify where improvements in prevention efforts are needed to reduce the substantive burden of prehospital fatal injury in New Zealand, serving to highlight the importance of strengthening both primary and secondary injury prevention efforts.

Ethics approvals

Ethics approval for the broader programme of research,[16] which this specific study is part of, was obtained from the National Coronial Information System (ref NZ007), University of Auckland Human Participants Ethics Committee (ref 016179) and University of Otago Health and Disability Ethics Committee (ref OTA/90/02/008/AM05).

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