Epidemiology of major trauma in New Zealand: a systematic review

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ABSTRACT

BACKGROUND: Physical injuries are one of the major causes of disability and death worldwide and have an immense impact on population health. In New Zealand, an estimated 8% of total health loss from all causes is attributed to injuries.

AIM: To describe the incidence and characteristics of major trauma in New Zealand.

METHODS: A systematic review based on a MEDLINE search strategy was performed using the databases PubMed, EMBASE, CINAHL and Scopus. Search terms included: "Wounds and Injuries," "Fatal Injuries," "Injury Severity Score," "Major Trauma," "Severe Trauma," "Injury Scale," "Epidemiology," "Incidence," "Prevalence" and "Mortality." Studies published in English up to September 2021 reporting the incidence of major trauma in New Zealand were included. The quality of studies was assessed using the GATE LITE™ tool.

RESULTS: Thirty-nine studies fulfilled the inclusion criteria. The majority of studies were descriptive observational studies (n=37). The incidence of fatal trauma was highest among those injured from motor vehicle crashes (MVCs) or falls, Māori males and those sustaining head injuries. The incidence of non-fatal major trauma was highest among young Māori males. MVCs and falls were the most common mechanism of injury among trauma patients across all age groups. Length of hospital stay was greatest in patients with the highest Injury Severity Scores.

CONCLUSIONS: The incidence of major trauma varies by age, sex and ethnicity. This review highlights the need for further analytical studies that can explore factors that may impact survival from major trauma.

Trauma, defined as any serious physical injury to the body that requires medical attention,[1] is one of the major causes of disability and death worldwide.[2,3] More than one quarter of the five million global deaths from physical injuries annually are the result of motor vehicle crashes (MVCs).[4] New Zealand (NZ) is a high-income country with a population of approximately 5.1 million.[5] Māori, the Indigenous people of New Zealand, account for 16.5% of the total population.[6] Around 50,000 people are hospitalised as a result of injury in New Zealand annually, with an economic cost estimated at NZ$10.2 billion per year.[7] An additional NZ$5.7 million is the estimated economic burden per fatality.[8] The New Zealand Ministry of Health (MoH) reported in 2016 that an estimated 8% of total health loss from all causes was attributed to injuries.[3] However, little is known about the incidence of injuries that have the potential to cause death or long-term disability (major trauma).[9]

Major trauma is commonly defined in terms of injury severity. Although there is not an internationally recognised definition of major trauma,[10] it has been variably defined as an Injury Severity Score (ISS) greater than 15, which is associated with a mortality risk of 10%.[11–14] Since the introduction of the Abbreviated Injury Scale (AIS) AIS-2005-Updated 2008, an ISS>12 is also considered as major trauma.[10,15–17]

In order to reduce morbidity and mortality resulting from major trauma, it is important to understand how major trauma is distributed in terms of time, geographic location and population groups. Therefore, this systematic review of the literature aimed to describe the incidence and characteristics of major trauma in New Zealand.

Methods

Inclusion criteria

Studies describing the incidence of major trauma in New Zealand published up to September 2021 were included. For the purposes of this review, "major trauma" was defined as death or an ISS greater than 12 or greater than 15, depending on the AIS version used at the time the injuries were coded.[11,17] The AIS is an anatomical scoring system used internationally to rank the severity of individual injuries by body region on a scale of 1 (minor) to 6 (un-survivable injury).[18,19] The AIS is the basis of the ISS, which is used to determine the

overall severity of multiple injuries.[20–23] The ISS is "the sum of the squares of the highest AIS grade in each of the three most severely injured areas"; its maximum score is 75, which is considered as the worst prognosis.[11,24] For the purposes of this review, in studies where ISS was not provided but the study included fatal and non-fatal cases, the deaths were assumed to be major trauma and thus were included.

The review considered all injury intents, all age groups, injuries resulting in admission to hospital, prehospital injury deaths and injury deaths occurring in hospital. Studies focusing on treatment injuries were excluded. Non-physical injuries that could not be scored by ISS such as drownings, poisonings and asphyxiations were also excluded (note codes for these three mechanisms were introduced in AIS 2005[25]).

Search strategy

Bibliographic computerised searches based on a MEDLINE search strategy were conducted in the following databases: PubMed, EMBASE, CINAHL and Scopus. Medical Subject Headings (MeSH) and keyword search terms used to identify published articles included: "Wounds and Injuries," "Fatal Injuries," "Injury Severity Score," "Major Trauma," "Severe Trauma," "Injury Scale," "Epidemiology," "Incidence," "Prevalence" and "Mortality." Additional electronic databases, the Te Hononga Whētuki ā-Motu, the National Trauma Network (formerly Major Trauma National Clinical Network (MTNCN)) website and the reference lists of all included studies were examined to identify any potentially relevant articles missed by the electronic search.

Limitations of English language, human population and New Zealand studies were applied. Searches were not restricted by date. LM conducted the initial search, LM and BK independently reviewed the title and abstracts.

Data extraction and appraisal

Duplicates were identified and removed before the titles and abstracts were screened by LM and BK. Full versions of studies potentially meeting the inclusion criteria were then reviewed, and ineligible studies excluded. The following information was abstracted from included studies: study design, information sources, study population, case definitions and main findings. The quality of studies was assessed using the GATE LITE™ critical appraisal form (www.epiq.co.nz).[26] The PRISMA guidelines were followed during data extraction, analysis and reporting.[27]

Results

The initial search identified 239 studies. Based on the title and abstract, 61 were considered potentially relevant. Of these, 39 studies fulfilled the inclusion criteria (Figure 1).

Study characteristics

The review period included studies published between 1987 and 2021. Out of the 39 studies included in this review, 19 were based on trauma registry data,[28–46] 11 were based on hospital or emergency medical services (EMS) records[47–57] and nine involved routinely collected national morbidity and mortality data from the MoH.[58–66]

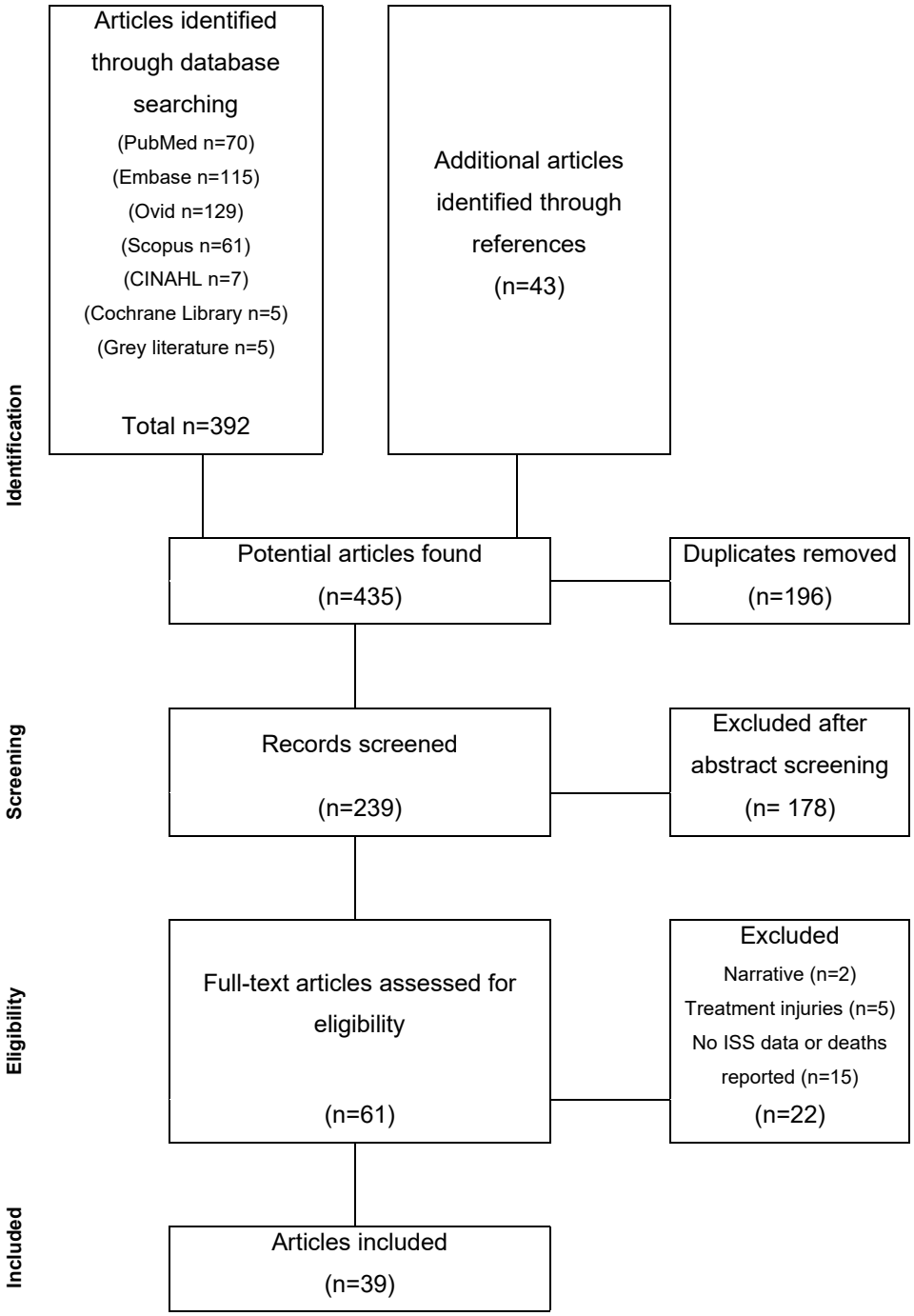
The majority of studies were descriptive observational studies (n=37), two were population-based cohort studies using prospectively gathered trauma database information from the Auckland region.[30,31] Twenty-one studies included people of all ages (Table 1), 11 included adults only (Table 2) and seven included children only (under 16 years) (Table 3). Five of the seven studies focusing on children focused on single mechanisms of injuries.[33,48,53,62,64]

The majority of studies included patients admitted to hospital following injury (n=16),[29–32,35–38,40,44,46,47,50,54–56] with two studies describing trauma admissions to the intensive care unit (ICU).[51,52] Four studies considered trauma due to all-terrain vehicles as a primary focus,[33,39,48,64] three studies included injuries occurring at home,[62,63,65] three studies limited to a particular injury type,[49,57,66] two studies considered penetrating trauma[28,45] and two studies described bicycle injuries.[34,58] Other single mechanisms of injury focused studies included pedestrian injuries,[53] motorcycle crashes,[59] work-related injuries,[41] animal-related injuries,[43] livestock-related injuries,[42] aircraft crashes[60] and river rafting injuries.[61]

The definition of major trauma was an ISS>12 in nine studies,[33–38,40,42,47] an ISS>15 or death in 16 studies[29–32,39,41,43,44,50–56,64] and death in 10 studies,[28,45,46,58,59,61–63,65,66] seven of which did not include information of ISS.[58,59,61–63,65,66] Four studies did not provide a clear definition of major trauma but reported data on ISS.[48,49,57,60]

Only 13 studies provided a full description of the characteristics of major tra uma.[30,31,35–37,46,47,55,58,59,61–63] The remaining stud-

Figure 1: Summary of study selection (PRISMA flow diagram).



ies presented information about the incidence of major trauma in trauma populations and the characteristics of trauma in general.

Due to the heterogeneity of included studies, it was not possible to explore trends in the characteristics and incidence of major trauma over the period reviewed.

Incidence of major trauma

Paediatric trauma

Among studies that described paediatric trauma, the proportion of major trauma cases among studies that focused on single mechanisms of injuries[33,48,53,62,64] ranged from 7%[48] for quad bike injuries to 95%[53] for pedestrian injuries (Table 3).

In contrast, the study that included all types of paediatric injuries that resulted in admission to hospital reported a prevalence of major trauma of 63%.[32] Studies that focused on a particular injury type showed a similar proportion of major trauma (5% for liver injury[57] and 6% for pelvic fractures[49]).

The study by Creamer et al analysed 2004 trauma registry data (all ages) from the Auckland region and reported a major trauma (ISS≥16) rate for children aged less than 15 years of 17/100,000, the lowest rate among all age groups.[30] Kool et al in their analysis of hospitalisations (2000–2009) and deaths (1999–2008) due to head injury reported that the lowest trauma rates were among children aged 5–9 (2.3/100,000).[66] However, Collins et al, in their review of pedal bicycle injuries among all ages resulting in death and hospitalisation (1979–1988), found that boys aged 10–14 had the second highest trauma rate (2.3/100,000).[58]

The studies reviewed showed that boys are more affected by major trauma than girls.[32,33,48,53,62,64] The review of national morbidity and mortality data by Collins et al found that boys aged 5–9 years and those aged 10–14 years had a higher incidence of major trauma (2.0/100,000 and 2.3/100,000 person-years respectively) than girls (0.6/100,000 and 1.3/100,000 respectively).[58] Kool et al found similar results where the incidence of major trauma was higher in boys than in girls aged 5–9 (2.7/100,000 cf. 1.9/100,000) and among those aged 10–14 (4.3/100,000 cf. 2.6/100,000).[66] Additionally, Creamer et al found that injury rates among boys aged 0–14 were approximately twice that of girls (23/100,000 cf. 12/100,000).[30]

Adult trauma

The proportion of major trauma cases among the total trauma cases reported in the adult population ranged from 4%[41] to 89%[51] in the studies reviewed (Table 2). A review of trauma registry data from the Auckland region (2004 data) by Creamer et al reported an overall major trauma (ISS≥16) incidence rate of 34/100,000 per year, with rates highest among young adults (15–29 years; 60/100,000) and older adults (≥75 years; 50/100,000).[30]

The studies reviewed showed that major trauma occurs most commonly among males.[40,41,44,45,47,51,61] The study by Gardiner et al of adult ICU trauma admissions to Auckland Hospital over a 10-year period (1988–1997) found that males had a significantly higher incidence of trauma than females (53.8 cf. 16.7 per 100,000 person-years).[51] These findings are consistent with a review of trauma registry records of work-related injuries in the Midland region (2012–2015) by Kool et al, who reported that rates among male workers were approximately five times greater (238/100,000 workers) than among females (44/100,000 workers).[41]

Additionally, the review of pedal bicycle injuries among all ages resulting in death and hospitalisation by Collins et al found that males aged 80 years or more had the highest trauma rate (3.5/100,000). However, the authors recommended treating this finding with caution because of the small number of fatalities in this group.[58]

Trauma among Māori

Although more than 35% of paediatric major trauma cases occurred among children of European origin[33,48,53,64] (range from 38%[53] to 89%[33]), Māori experienced the highest trauma rates (Table 3).[31,53] The review of trauma registry data of injured child pedestrians (<15 years) admitted to Auckland Hospital (1986–1989) by Roberts et al. reported higher trauma rates among Māori children (13.2/100,000) than children of European origin (4.2/100,000).[53] These findings are consistent with the population-based study of trauma registry data by Creamer et al, who reported that injury rates among Māori males aged 0–14 years were higher (50/100,000 per year) than among other ethnicities combined (12/100,000 per year).[31] However, the same study showed that for females aged 0-14 years, the incidence rate among Pacific children was almost double the rate among Māori children (35/100,000 cf. 19/100,000).[31]

Adult trauma rates were higher among Māori than other ethnicities.[31,51,58] The population-based study by Creamer et al of trauma registry data reported higher major trauma (ISS≥16) rates

among Māori (61.4/100,000 per year) and Pacific people (39/100,000 per year) compared to people of NZ European and other ethnicities combined (29/100,000 per year).[31] Gardiner et al found similar results among adult ICU trauma admissions, where the rates for Māori and Pacific patients were greater (123/100,000 and 70/100,000 respectively) than for NZ European patients (36/100,000).[51]

For all age groups, the review of major trauma admissions for Māori in the Canterbury region (2006–2018) by Kandelaki et al showed that 9% of major trauma cases occurred among Māori, with Māori males the most affected (75%).[35] It also reported similar incidence rates among Māori and other ethnicities (57.9/100,000 cf. 57.3/100,000).[35]

Although trauma incidence rates among males[40,41,44,45,47,51,61] and Māori[31,51,58] were highest in most studies reviewed, a review by O'Leary et al of older adult (≥65 years) trauma cases from the Midland trauma registry between 2012 and 2014 found that injury rates were higher among females (608/100,000) than males (557/100,000) and non-Māori than Māori (594/100,000 cf. 460/100,000).[40]

Mechanism of injury

Blunt trauma accounted for more than 80% of all trauma-related admissions among all ages in the studies reviewed (Table 1).[32,42,51,54–56] MVCs and falls were the most common mechanism of injury among trauma patients across all age gro ups.[31,32,36–38,40,47,51,54,59] The review of Midland trauma registry data by Kool et al reported that contact with machinery (26%) and falls (19%) were the most common cause of work-related injuries.[41] Couch's review of trauma records of 82 children (<15 years) admitted to two child emergency departments (ED) over one-year period found that MVCs accounted for 57% of all trauma, of which 61% involved pedestrians. Additionally, falls and other mechanisms in this age group (including non-accidental injury) accounted for 34% and 12% of injuries, respectively.[32]

This review found that, although major trauma due to falls is common across all age groups in New Zealand, the incidence is highest in older adults (≥65 years).[40,52,67] The review of older adult trauma cases in the Midland trauma registry published by O'Leary et al found that among older major trauma (ISS≥13) patients, the prevalence of MVCs was higher than the prevalence of falls in this age group (43% cf. 39%).[40]

Among the studies that analysed trauma due to pedal cycles, motorbikes or all-terrain vehicles, the main mechanisms of injury were falls from the vehicle and collisions with motor vehicles.[39,48,58,64] Wood et al reviewed data from the Waikato Hospital trauma registry on major trauma patients (ISS>15) with quad-bike related injuries between 2007 and 2011 and found that the main mechanism of injury was rollovers (37%).[39]

Studies analysing animal and livestock-related injuries reported that falls from horses (81%) and being hit by cattle, sheep, pigs or goats were the most common cause of injuries, respectively.[42,43] Penetrating injuries were uncommon.[28,45]

Severity

The head was the most commonly injured body region in major trauma patients in the studies included in this review.[32,39,40,48,51,53,56,58,66] The prevalence of head injuries ranged from 26%[48] in a review of quad bike injuries in children to 100%[66] in a study of incidence and mortality due to head injury. Pearce's review of paediatric ICU (PICU) records found that, in children under 16 years of age admitted to Starship Children's Hospital between 2007 and 2014 with head injuries due to a quad bike incident, the mean ISS was 19.4 (range 5–43), which was slightly higher in those who were not wearing helmet at the time of the injury (mean ISS 21.8; range 9–43).[48]

Upper and lower extremity injuries were common among major trauma cases. However, these did not represent life threatening injuries.[33,34,41–43] Singh et al found that 52% of cycling-related injuries involved extremities.[34] A study of major work-related trauma by Kool et al,[41] and a study of injuries due to animals by Johns et al[43], which reviewed trauma registry data, found similar proportion of extremity injuries (48%[41] and 49%[43] respectively).

A study by Civil et al of 114 patient hospital records over a six-month period found that 40% of patients with major injuries admitted to hospital had an ISS between 16 and 24, and that no patients with an ISS≥50 survived.[55] Safih et al, in their review of Auckland Hospital ICU records, found no difference in the mean ISS between younger (<65 years) and older adult (≥65 years) patients (26 cf. 25).[52] Similar results from among patients with liver injuries were reported by Wakeman et al, who did not find difference in the mean ISS (17.5 cf. 17.0) between paediatric (0–17 years) and adult population (≥18 years).[57] However, the study of Starship PICU records by Pearce et al found that ISS was higher in children under 5 years of age (mean ISS 22.3) compared to children aged 5–10 years of age (mean ISS 10.5).[48]

In terms of ethnicity, the study by Wood et al that examined data from 101 Waikato Hospital trauma registry cases with quad-bike related injuries found that Māori had a significantly higher mean ISS compared to their NZ European counterparts (16.8 cf. 10).[39]

Three of the studies reviewed reported an association between length of hospital stay (LOS) and ISS.[43,47,50] Czuba et al, in a cohort of 112 patients with major trauma (ISS≥12) from two hospitals in Auckland, found that the median LOS was greater in patients with higher ISS. The results of this study showed that patients with an ISS≤25 stayed in hospital for a maximum 10 days, whereas patients with an ISS>25 were in hospital between 22 and 25 days.[47]

Deaths occurring among major trauma patients

The proportion of deaths among major trauma patients in the studies reviewed ranged from 1%[39] to 30%.[55] An age gradient was evident in some studies, with an in-hospital case fatality rate approximately twice as high in older patients (≥65 years) compared to younger (<65 years) patients (28% cf. 13%; p<0.001).[29,52] The review of national morbidity and mortality data (1989 to 1998) by Gulliver et al, where they examined injuries sustained in the home among young children (<5 years of age), found that mortality rates reduced as age increased. Annualised mortality rates among children aged 0–11 months were 28/100,000 compared with 5/100,000 among children aged 48–59 months.[62] Collins et al, in their review of pedal bicycle injuries resulting in death and hospitalisation (1979–1988), found that 39% of the fatalities occurred in children between 5 and 14 years old.[58] However, in their review of head injuries resulting in death (1999–2008) and hospitalisation (2000–2009), Kool et al found that only 4% of the fatalities occurred in children between 5 and 14 years old.[66]

The study by Langley et al which reviewed national mortality data relating to motorcycle crashes (1978–1987) reported a mortality rate of 3.5/100,000 persons per year for all age groups, with males experiencing higher rates than females in those aged 15–24 years (3.4/100,000 cf. 2.0/100,000).[59] Similarly, in their study of people aged 25–59 years who died as a result of unintentional falls at home, Kool et al found the fatality rate for males was three-times higher than the female rate (0.63/100,000 cf. 0.20/100,000).[63]

Mortality rates in the studied reviewed also varied by ethnicity. Although Māori accounted for less than 30% of all trauma-related deaths[31,59,65] (range from 9%[59] to 25%[65]), this group experienced the highest fatality rates. The Auckland regional study by Creamer et al of trauma registry data (ISS>15) reported higher injury mortality rates among Māori (28.4/100,000 per year) and Pacific (16.4/100,000 per year) compared to NZ European and other ethnicities combined (11.9/100,000 per year).[31] Kool et al found similar results in patients aged 20–64 years for unintentional injuries that occurred at home, with fatality rates of 5.4/100,000 among Māori and 3.0/100,000 for NZ European.[65] However, the review of major trauma admissions for Māori conducted by Kandelaki at al showed that the proportion of deaths was lower for Māori compared to other ethnicities (5% cf. 11%).[35]

The main causes of death in major trauma patients in the studies reviewed were MVCs[30,31,46,58] (range 32%[46] to 88%[58]) and falls[30,31,46,63,65] (range 10%[46] to 23%[31]). The study of unintentional injuries occurring at home resulting in death (1998–2007) or hospitalisation (2000–2009) conducted by Kool et al found that over a 10-year period burns were one of the main mechanisms of injury resulting in death (12%).[65]

In relation to the nature of injuries sustained, head injuries were common (60%–100%) among fatal injury cases.[58,66]

Impact of COVID-19 in major trauma admissions

Coronavirus disease 2019 (COVID-19) has changed the live and daily routine of many people around the world. Due to its rapid spreading, the World Health Organization (WHO) declared it as a global pandemic on 11 March 11 2020.[68] Two weeks later, on 25 March at 11:59pm, New Zealand moved to level 4 (lockdown), the highest level of a four-level alert system announced by the New Zealand Government, in order to eradicate the virus and avoid overburdening the healthcare systems.[36,37,69] Although the effects of the lockdown are yet unknown, some studies conducted in New Zealand have shown a significant impact on the number of major trauma admissions.[36–38]

The study conducted by Christey et al of trauma patients admitted to a level one trauma centre in New Zealand pre-lockdown (5–18 March 2020) and during lockdown (26–April 8 March 2020) showed a reduction of 50% in all major trauma admissions. This study also found that it was a decrease in the number of trauma admissions for males (50% reduction), children aged 0–14 years (48%

reduction) and Māori (39% reduction). Although it was a significant reduction in the number of trauma admissions due to falls and MVCs (48% and 74%, respectively), these continue being the most common mechanism of injury during lockdown in New Zealand.[38] Similarly, in their study of major trauma patients admitted to Christchurch Hospital before (22 February–25 March), during (26 March–27 Arpil) and after lockdown (28 April–30 May), Fan et al found a 42% reduction in the number of major trauma admissions during lockdown in all sex and age groups. The most common mechanism of injury before and after lockdown was transport-related injuries. However, during lockdown falls were the most common injury (48%). Road and home were the most common places of injury across all periods.[37]

The study by McGuinness et al, which reviewed major trauma registry data in the Northern Region (16 March–8 June 2020, and in the same period in 2019), reported a decreased in major trauma admissions of 25% in 2020 compared to 2019. Although it was a reduction in age, gender, mechanism of injury, type of injury and injury intent, the differences were not statistically significant. An increase in the number of injuries occurring at home was observed in 2020 compared to 2019 (35% cf. 20%).[36]

Discussion

The aim of this review of the published literature was to describe the incidence and characteristics of major trauma in New Zealand. Thirty-nine studies met the review eligibility criteria. The studies included were mainly descriptive observational studies that had analysed routinely collected data from trauma registries, hospital records or national morbidity and mortality data. The proportion of major trauma reported in the studies reviewed was variable, ranging from 4%[41] to 95%.[53] This in part reflects the heterogeneous case definitions used, and the different populations studied (eg, trauma registry data cf. MoH morbidity and mortality data).

The results demonstrate that differences in trauma rates exist in New Zealand by sex, ethnicity and age. This review found rates of major trauma are highest among young adults (15–29 years) and older people (≥75 years), and lowest among children aged 0–14 years.[30,58] These findings are consistent with a review of Japan's trauma registry data by Kojima et al, which found that moderate to major trauma (ISS≥9) occurs most commonly among elderly people aged 60 years or older (53%), and less common among children (9%).[70]

This review also showed that in both the paediatric and adult populations, males[32,33,40,41,44,45,47,48,51,53,61,62,64] and Māori[31,51,53,58] are the subgroups most affected by major trauma in New Zealand. These results are consistent with data from annual report (2018–2019) of the New Zealand Major Trauma Registry & National Clinical Network (MTNCN), which showed the incidence of major trauma was higher among males in all age groups, and that Māori experienced higher major trauma rates (56/100,000) than non-Māori (43/100,000).[71]

Blunt trauma due to MVCs and falls were the main mechanisms of trauma resulting in hospitalisation and death in New Zealand in this rev iew.[30–32,36–38,40,42,46,47,51,54,56,58,59,63,65] For the paediatric population, these findings are consistent with a review of five years of data from a Swiss trauma registry, which found blunt trauma represented 92% of all admissions and that 42% of the patients had major injuries (ISS>15), of which 76% were males with injuries primarily due to falls (40%) and MVCs (34%).[72]

Chico-Fernández et al reported that 79% of the trauma patients admitted to ICU in Spain (2012–2015) were young men, and that the main mechanism of injury was falls (37%).[73] A study conducted in Australia by Harris et al, which included 355 patients with major trauma, found that 63% of the cases were due to MVCs and that males were more overrepresented (72%).[74] Similar results were found by Alberdi et al in another Spanish study investigating the epidemiology of severe trauma in all age groups, where the main cause of trauma among patients aged 15–25 years was road traffic related injury, and that older patients (>65 years) had a greater mortality rate than younger people (35% cf. 15%).[75]

Major trauma studies in Australia have found that males aged between 15 and 24 years account for the majority of all trauma admissions, with blunt trauma from MVCs being the main cause of injury.[76,77] However, the New Zealand MTNCN's annual report (2018–2019) showed that there are three age peaks (15–29, 45û60 and 85+), with the 15–29 age group having the greatest burden of injury.[78] Although patterns of trauma are similar in Australia and New Zealand, incidence rates differ.[77] According to the Victorian State Trauma, the incidence of major trauma in 2016–2017 was 55/100,000,[79] which is greater than that reported by the New Zealand MTNCN in 2018–2019 (48/100,000).[71]

In the current review, among major trauma patients the head was the most common body region injured. [32,39,40,48,51,53,56,58,66] A Spanish study conducted by Rastogi et al of 748 patients (all ages) admitted to a major trauma centre in India reported 57% of patients had sustained head injuries.[80] Alberdi et al, in their study of the epidemiology of severe trauma in Spain, found a lower prevalence (33%–47%).[75] The Spanish studies both identified a statistically significant association between ISS and mortality.[73,75] The studies included in this review suggest that length of stay in hospital is influenced by ISS.[43,47,50] However, the relationship between ISS and mortality could not be examined in this review because seven of the 10 included studies defined major trauma as death and did not include information about ISS.[58,59,61–63,65,66]

Trauma admissions in New Zealand have experienced a decrease during the COVID-19 pandemic,[36–38,81] mainly due to the restrictions on the free movement orchestrated by different governments around the world, reinforcing the notion that trauma is a social disease. The studies reviewed reveal a reduction of more than 40% in major trauma admissions during lockdown, with the greatest reductions observed in males, children aged 0–14 years and MVCs.[36,37] The New Zealand MTNCN's annual report (2019–2020) showed the incidence of major trauma was lower in 2019/20 than in 2018/19 (44/100,000 cf. 48/100,000) and reported a 50% reduction in major trauma admissions across the country during the initiation of level 4 (lockdown), mainly due to changes in transport injuries.[82] Similar results were found in a study conducted in South Australia by Harris et al, who reported a 33% reduction in major trauma admissions, especially for those aged 40 years or older and for transport-related trauma (45% reduction in each case).[83]

Strengths and limitations

This review provides a useful summary of studies of major trauma in New Zealand that have been published up until September 2021, providing historical context for those working in the trauma or injury prevention fields. The strength of this review includes a rigorous methodology to identify relevant studies through an exhaustive search of the current data in multiple electronic databases. Two independent reviewers (LM and BK) performed the literature search, selected and evaluated the quality of the articles, which enhanced validity and reliability. Results have been reported following the PRISMA guidelines.[27]

The strengths of studies included in this review that analysed data from the MoH[58–66] include the ability to explore trends over time, and the population-based nature of the data. However, MoH morbidity databases do not include trauma-specific injury severity indices,[58] which explains why information related to ISS was not reported in some articles or had to be calculated in others using the AIS. Comparisons of findings between studies were difficult due to the differences in sample sizes, population groups and major trauma definitions.

The review findings need to be considered in light of some limitations. The review period included studies from 1987 to 2021, a time during which there were a number of AIS revisions,[19,25] resulting in potential differences in how major trauma is defined and having a potential impact on injury research. Since the development of AIS in 1971 by the Association for the Advancement of Automotive Medicine (AAAM), there have been some updates,[15,25,84] the most recent being the AIS 2015.[19,85] The AIS 2005 update brought significant changes in scores for some body regions, in particular for the thorax and head regions.[15,84] The 2008 update provided further refinements to the classification deficits.[20,25] The AIS 2015 update improved brain injury and spinal cord coding.[85] Palmer et al noted that there is a significant decrease in the number of patients classified as major trauma when converting AIS98-coded data to AIS08.[86] From the information provided, 48% of the studies included in this review used the AIS98 or previous versions, and the remaining studies used the AIS05/08 versions. Given the findings of Palmer et al, this may mean the earlier studies in this review may have overestimated the severity of injury reported.

Another limitation is the ability to calculate an overall estimate of the incidence of major trauma in New Zealand; this is challenging due to the lack of a clear definition of major trauma in included studies, and difficulties in comparing trauma registry studies with non-trauma registry studies due to the exclusion of non-physical trauma in the former (eg, poisoning, asphyxiation and drownings). Although ISS has been recognised as the "gold standard" scoring system for trauma, it has substantial limitations.[11,12,24,87] Firstly, ISS scoring is expensive as a significant amount of time and effort is required for AIS collection.[88,89] Moreover, the scored injuries are often not even the three

most severe injuries as the ISS only considers at most only three of a given patient's injuries, one per body region.[11,24] Additionally, it does not take account for contextual information such as comorbidities and issues relating to the event itself that may have contributed to patient outcomes.[89] A study of the accuracy of injury coding in New Zealand by Davie et al found, in a random sample of public hospital discharges, that 14% of the principal injury diagnosis and 26% of the external cause codes had inaccuracies, which were identified on the first, second or third characters.[90] This is likely to have affected the completeness of case ascertainment in the studies reviewed.

Only half of the studies reviewed reported ethnicity. Previous New Zealand research has highlighted that Māori are disproportionally represented in national injury data.[91,92] Additionally, it has been found that ethnicity reported on the national systems can differ to what patient identifies. The study of Scott et al evaluated the quality of ethnicity data (self-reported compared to that recorded by the Waikato Hospital trauma registry) and found the percentage of self-identified ethnicity that mismatched trauma registry ethnicity was 21% for Māori compared to 4% for non-Māori.[93]

There was limited South Island data included in the published studies reviewed. The majority of studies found were conducted or included data from the North Island, especially from Auckland and the Waikato region. Trends over time were unable to be described due to the heterogeneity of the included studies.

There is a scarcity of data relating to ethnicity, and major trauma among children in the international published literature which makes it difficult to compare the findings of this review with those from other countries.

Conclusion

The incidence of major trauma in New Zealand varies by age, sex and ethnicity. Although the New Zealand MTNCN has provided national level data on the incidence and outcomes of major trauma since 2015, the findings of this review highlight the need for further analytical studies that can explore factors that may impact survival from major trauma and continued efforts to prevent injuries in New Zealand. Changes in major trauma admissions during the COVID-19 pandemic as part of public health interventions, reinforce the notion that trauma is a social disease.

Table 1: Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Streat SJ (1987)[56]	569 patients who died or were admitted to hospitals in the Auckland Hospital Board region as result of trauma between 15 November and 12 December 1982 Major trauma was defined as ISS≥16	9% major trauma Median ISS=5 (range: 1–75) MVCs 64% Head injury 53% 3% died	No ethnicity data reported - Only one month of data included in the study
Civil I (1987)[55]	114 patients who presented to the emergency department (ED) of Auckland Hospital following injury between 1 July to 31 December 1983 Major trauma was defined as ISS≥16	53% with an ISS of 16–24 82% blunt trauma due to falls or MVCs 30% died	No ethnicity data reported
Civil I (1988)[54]	602 patients presented to the ED of Auckland Hospital following injury during 1983 Major trauma was defined as ISS≥16	37% major trauma MVCs 58% and falls 25% 10% died	Only included information from Auckland Hospital Injured patients were taken to the closest hospital, which could mean an under representation of the trauma cases No ethnicity data reported
Safih MS (1999)[52]	2,092 patients with severe trauma admitted to the ICU of Auckland Hospital between January 1987 and December 1996 Major trauma was defined as ISS≥16 or death	*Older group ≥65 years (n=183; 9%)* Median ISS 25 ; ISS≥16 80% MVCs 57% and falls 34% Mortality 28% *Younger group <65 years (n=1909; 91%)* Median ISS 26 ; ISS≥16 89% MVCs 67% and falls 13% Mortality 14%	Information of ethnicity was available from 1989
Mittal A (2001)[50]	75 patients admitted to Auckland Hospital following trauma between December 1999 and January 2000 Major trauma was defined as ISS>15	22% <50 years had major trauma 14% ≥50 years had major trauma Length of stay (LOS) 19 days for patients with no co-morbidities LOS 24.5 days for patients with co-morbidities	Information of ethnicity and sex was not reported

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Wakeman C (2003)[57]	93 patients with liver injuries admitted to Christchurch Hospital over a five-year period (1996-2000) NB. "major trauma" not defined. ISS is reported	*Paediatric population 0–17 (n=22; 23.7%)* Median ISS 17.5 (range 4–59) LOS 4 days (range 1–12) Mortality 5% *Adult population ≥18 (n=71; 76.3%)* Median ISS 17.0 (range 5–50) LOS 8 days (range 1–52) Mortality 13% (ISS 32)	Information of ethnicity and sex was not reported
National morbidity/mortality data-based studies			
Collins BA (1993)[5]	238 cases of pedal cycle injuries resulting in death between 1979 and 1988 NB. ISS not reported but injury-related deaths	88% collisions with motor vehicles 60% had head injuries 39% of fatalities aged 5–14 years Mortality rate 0.8/100,000 persons/year	No ethnicity data reported The nature of injury was not specified for a small proportion of the deaths
Langley JD (1994)[59]	1,175 cases of motorcycle crashes resulting in death between 1978 and 1987 NB. ISS not reported but injury-related deaths	96% MVCs Mortality rate 3.5/100,000 persons/year	The body regions injured were not specified
Chalmers DJ (2000)[60]	224 cases of aircraft crashes and related events in civil aviation, resulting in hospitalisations (1988–1993) and death (1988–1992) NB. 'major trauma' not defined. ISS by groups is reported	Hospitalisations (n=120; 54%): ISS≥20 3.3% 38% involved fixed-wing aircraft Fatalities (n=104; 46%): ISS≥20 82% 53% involved fixed-wing aircraft	No ethnicity data reported ISS could not be calculated in 17 cases of death A clear definition of major trauma was not provided

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Kool B (2013)[66]	51,912 people (all ages) admitted to hospital between 2000 and 2009 or who died between 1999 and 2008 as result of head injuries NB. ISS not reported but injury-related deaths	Hospitalisations (n=47,565; 92%): Incidence rate 118.1/100,000 Higher incidence rates in males Highest incidence rates for Māori Mortality 2% Fatalities (n=4,347; 8%): Mortality rate 10.8/100,000 Mortality rate in aged ≥65 21/100,000 Mortality rate in aged 15–24 17.3/100,000 Highest mortality rates for Māori	Under-estimation of head injuries due to the inclusion of cases with a principal diagnosis of head injury
Trauma-registry-based studies			
Pang JM (2008)[46]	186 trauma deaths (all ages) occurred between 1 January 2004 and 31 December 2004 in the Auckland region NB. ISS not reported but injury-related deaths	Median ISS=25 (range: 1–75) MVCs 32% Hanging 36%	No ethnicity data reported Inclusion of hanging could affect the median ISS
Creamer GL (2008)[30]	448 patients (all ages) with severe injuries (ISS>15 or death) admitted to hospital during 2004	Injury rate 33.6/100,000 MVCs 50% and falls 19% Hangings 15% (all resulted in death) Mortality rate 14.4/100,000	No ethnicity data reported

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Creamer GL (2010)[31]	448 trauma patients (all ages) admitted to one of the four hospitals in Auckland region, with an ISS>15 or who died as result of injury during 2004	Māori (n=95; 21%): MVCs 45% Hanging 25% Assault 18% Injury rate 61.4/100,000 Mortality rate 28.4/100,000 Pacific (n=66; 15%): MVCs 44% and falls 23% Assault 14% Injury rate 38.6/100,000 Mortality rate 16.4/100,000 Other (n=287; 64%): MVCs 52% Hanging 22% Assault 12% Injury rate 28.5/100,000 Mortality rate 11.9/100,000	The data used to calculate the rates were projections
Wood A (2013)[39]	101 trauma patients (all ages) admitted to Waikato Hospital between February 2007 and March 2001 as result of quad bike-related injuries Major trauma was defined as ISS>15 or death	27% major trauma 37% rollovers 26% collisions 29% head injury 1 death (traumatic brain injury)	Single-centre study Information of rural hospitals in the Waikato region was not included, which could cause an underestimation of the quad bike injuries
Tosswill M (2018)[42]	168 trauma patients (all ages) admitted to a Midland hospital with livestock-related injury from 2012 to 2015 Major trauma was defined as ISS>12	5% major trauma Mean ISS=3.6 (highest ISS=22) 76% cattle-related 7% head injuries 40% upper/lower extremity injuries Mean LOS=2.3 days	Injuries treated in the community were not included

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Burstow M (2019)[29]	26,882 patients (all ages) admitted to Auckland hospital between 1995 and 2014 following trauma Major trauma was defined as ISS≥16	<65 years (n=22,454; 84%) 18% major trauma Median ISS=4 (IQR*: 4–10) 37% falls 2% died (13% with an ISS≥16) ≥65 years (n=4,428; 16%) 15% major trauma Median ISS=4 (IQR*: 4–9) 72% falls 6% died (28% with an ISS≥16)	No ethnicity data reported
Singh N (2019)[34]	998 patients (all ages) admitted to hospital between 1 June 2012 and 31 July 2016 as a result of cycling-related injuries in the Midland Region Major trauma was defined as ISS≥13	8% major trauma 15% Māori 62% occurred in road 52% upper/lower extremity injuries Injury rate 21.1/100,000 in males aged≥20 years (2013-2014) Injury rate 9.4/100,000 in females aged≥20 years (2015-2016)	Injury patients who died pre-hospital were not included
Christey G (2020)[38]	195 trauma patients (all ages) admitted to a level one trauma centre between March 5–18 2020 and March 26 to April 8 2020 Major trauma was defined as ISS>12	Pre-lockdown (n=124; 64%): Major trauma 18% 68% male 29% Māori 37% falls 33% home injuries During lockdown (n=71; 36%): Major trauma 15% 59% male 31% Māori 34% falls 48% home injuries	Single centre experience

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Kandelaki T (2021)[35]	702 patients (all ages) with major trauma admitted to Christchurch Hospital between 1 June 2016 and 31 May 2018 Major trauma was defined as ISS≥13	Māori (n=63; 9%): 75% male 44% MVCs 22% falls 5% mortality Other (n=639; 91%): 69% male 45% MVCs 30% falls 11% mortality	Possible incorrect ethnicity entry data in the Waikato trauma registry
McGuinness MJ (2021)[36]	286 patients (all ages) with major trauma admitted to hospitals in the Northern Region between 16 March to 8 June 2019 and the same period but in 2020 Major trauma was defined as ISS>12 or death	2020 (n=123; 43%): 31% falls ; 30% MVCs 97% blunt trauma Mean ISS 20±8.6 14% mortality 2019 (n=163; 57%): 25% falls ; 36% MVCs 91% blunt trauma Mean ISS 20±8.5 12% mortality	Small sample size No ethnicity data reported

Table 1 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (all ages).

Study	Participants	Findings	Comments
Fan D (2021)[37]	83 patients (all ages) with major trauma admitted to Christchurch Hospital between 22 February 2020 and 30 May 2020 Major trauma was defined as ISS≥13	Pre-lockdown (n=36; 44%): Mean ISS 21±9.1 89% male 31% falls 50% transport-related injuries During lockdown (n=21; 25%): Mean ISS 22±6.1 81% male 48% falls 38% transport-related injuries Post-lockdown (n=26; 31%): Mean ISS 21±9.1 (level 3) Mean ISS 19±7.5 (level 2) 85% male 31% falls 46% transport-related injuries	Single centre experience No ethnicity data reported Small sample size

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor vehicle crashes; ED: Emergency department; LOS: Length of hospital stay; ICU: intensive care unit.

Table 2: Epidemiology of major trauma in New Zealand: summary of included studies (adults).

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Gardiner JP (2000)[51]	2,305 trauma admissions to the ICU of Auckland Hospital from 1 January 1988 to 31 December 1997 Major trauma was defined as ISS≥16	89% major trauma Median ISS 26 (range: 1-75); ISS≥25 64% MVCs 66% 63% of critical injuries were the head and neck region	Information of ethnicity was available from 1989
Czuba KJ (2019)[47]	112 injured patients≥18 years old with an ISS>12 admitted to one of the two trauma centres in Auckland between 15 June 2015 and 14 December 2016	24% with an ISS of 12–15 36% with an ISS of 16-20 MVCs 30% and falls 28% Median LOS greater in patients with higher ISS: ISS 12-20: 7 days ISS 21-25: 10 days ISS 26-30: 22 days ISS>30: 25 days	Only 54% of the eligible population was included
National morbidity/mortality data-based studies			
O'Hare D (2002)[61]	33 cases of injuries associated with white water and other recreational river rafting resulting in death between 1983 and 1995 NB. ISS not reported but injury-related deaths	Drowning 94% 36% due to the raft capsizing	No ethnicity data reported Small sample
Kool B (2007)[63]	73 people aged 25–59 years who died as a result of an unintentional fall-related injury occurring at home between 1993 and 2002 NB. ISS not reported but injury-related deaths	Falls from buildings or structures 26% Falls involving stairs or steps 19% Fatality rate for males 0.63/100,000 Fatality rate for females 0.20/100,000	No ethnicity data reported The type of fall was not specified for 25% of the fatalities

Table 2 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (adults).

Study	Participants	Findings	Comments
Kool B (2011)[65]	40,986 people aged 20–64 discharged from hospital between 2000 and 2009 or who died between 1998 and 2007 as result of unintentional injuries occurring at home NB. ISS not reported but injury-related deaths	Hospitalisations (n=40,382; 99%): 0.6% major trauma Falls 45% Cutting/piercing 17% Deaths (n=604; 1%): Falls 21% Burns 12% Poisoning 38% (Drug-related 78%)	Overestimation of injury incidence due to the inclusion of cases without a diagnosis code and because the no compensation of the cases admitted and discharged in a reference year
Trauma registry-based studies			
Civil I (1998)[28]	96 patients aged≥16 years admitted to Auckland Hospital following penetrating trauma in 1995 NB. ISS not reported but injury-related deaths	4.2% major trauma 75% of major trauma intentional Median ISS=22 (range: 9–75)	The body regions injured were not specified No ethnicity data reported
Johns E (2004)[43]	167 adult (≥15 years of age) admissions to Auckland Hospital for animal-related injury from December 1994 to April 2001 Major trauma was defined as ISS>15 or death	14% major trauma (including 2 deaths) Median ISS=4 (range: 1-32) 86% associated with horses 49% involved the extremities LOS influenced by the ISS (Mean=4 days; range: 1-62)	No ethnicity data reported
Tan C-P (2004)[44]	105 trauma patients aged≥40 years admitted to Auckland Hospital between 1 January and 3 March 2003 Major trauma was defined as ISS>15	15% major trauma 5% died due to head injury	No mechanism of injury and ethnicity data reported

Table 2 (continued): Epidemiology of major trauma in New Zealand: summary of included studies (adults).

Study	Participants	Findings	Comments
Hsee L (2008)[45]	56 trauma patients aged≥15 years admitted to hospital or who died as a result of gunshot injuries between 1995 and 2006 NB. ISS not reported but injury-related deaths	7% major trauma due to brain trauma (ISS range: 25-75) Median ISS 10 (range: 1–75) 52% unintentional injuries Extremities injuries 38%	No ethnicity data reported
O'Leary K (2017)[40]	2,278 trauma patients aged ≥65 years admitted to hospital in the Midland region between 1 January 2012 and 31 December 2014 Major trauma was defined as ISS>12	10% major trauma 98% unintentional injury Falls 39% Transport related injury 43% Chest injuries 22% Head or neck injuries 22% LOS≥10 days: 31%	Information of ethnicity was obtained directly from the patients
Kool B (2017)[41]	2,169 trauma patients ≥15 years old admitted to a Midland hospital with work-related injuries between 1 January 2012 and 31 December 2015 Major trauma was defined as ISS>15	4% major trauma Median ISS=2 (IQR*: 1–4) Falls 19% Injury caused by contact with machinery: 26% Extremities injuries 48%	Pre-hospital deaths were not included

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor vehicle crashes; LOS: Length of hospital stay; ICU: Intensive care unit.

Table 3: Epidemiology of major trauma in New Zealand: summary of included studies (paediatric population).

Study	Participants	Findings	Comments
Patient hospital/ambulance record-based studies			
Roberts I (1991)[53]	64 children under 15 years of age injured as pedestrians and admitted to the Department of Critical Care Medicine (DCCM) of Auckland Hospital between 1986 and 1989 Major trauma was defined as ISS≥16	95% major trauma Median ISS=29 (range: 4–75) 83% of critical and severe injuries were in the head region 14% died (all from brain injuries)	Information of ethnicity (census and hospital data) was based on parent report ethnicity
Pearce R (2015)[48]	27 children under 16 years of age with confirmed quad bike injuries and admitted to Starship Children's Hospital from January 2007 to July 2014 NB. 'major trauma' not defined. ISS by age groups is reported	Mean ISS 14 (range: 1–75) ISS 33.8 (range: 9-75) for PICU admissions 26% head injury (Mean ISS 19.4; range: 5-43) 7% died	Only 59.2% had information about the quad bikes A clear definition of major trauma was not provided Small sample
Bajaj M (2018)[49]	179 children with a pelvic fracture admitted to Starship Hospital between July 1995 and May 2015 NB. 'major trauma' not defined. ISS is reported	Mean ISS 9 (IQR: 4–22) Severe traumatic brain injury 19% Pedestrian struck by a vehicle 46% MVCs 23% Mortality 6% (ISS 36.5; range 17–59)	No ethnicity data reported
National morbidity/mortality data-based studies			
Gulliver P (2005)[62]	355 deaths in children under 5 years occurring in the home between 1989 and 1998 NB. ISS not reported but injury-related deaths	Suffocation 36% Homicide rate 2/100,000 children per year	No ethnicity data reported
Anson K (2009)[64]	218 children under 16 years old hospitalised because of ATV-related injury between 2000-2006 Major trauma was defined as ISS>15 or death	Median ISS 9 (range: 4–9); ISS>15 8% Falls from vehicles 49% 6 admissions to PICU 8% died	Data related to ethnicity was not available for 7 patients Limited information about deaths

Study	Participants	Findings	Comments
Trauma registry-based studies			
Couch L (2010)[32]	82 children aged <15 years admitted to hospital as result of trauma between 1 May 2003 and 30 April 2004 Major trauma was defined as ISS>15	Starship Hospital (n=40; 49%) 63% major trauma MVCs 48% and falls 38% 80% head injury KidzFirst (n=42; 51%) 62% major trauma MVCs 60% and falls 31% 77% head injury 1 death (ISS=38)	Small sample size, which affected statistical power. Not all injury presentations were included Problems in defining moderate trauma
Scott A (2011)[33]	146 children under 15 years old admitted or died in Starship Children Hospital between 1 November 1999 and 31 December 2008 as result of motorcycle trauma Major trauma was defined as ISS>12	Motorbikes (n=123; 84%) 9% major trauma Median ISS=3.1 (range: 1–35) 2 deaths due to head injuries All-terrain vehicles (n=23; 16%) 26% major trauma Median ISS=4 (range: 1-25)	The lethality of motorcycles could be underestimated because coroner's records for deaths outside hospital were not searched

Abbreviations: *IQR: Interquartile range; ISS: Injury Severity Score; MVCs: Motor vehicle crashes; PICU: Paediatric intensive care unit; DCCM: Department of Critical Care Medicine.

COMPETING INTERESTS
Luisa Montoya declares receiving fortnightly payments from the University of Auckland between September 2019 and February 2022 for their PhD studies (Research Project Scholarship).

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