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ATV (quad bike) injuries in New Zealand children: their extent and severity

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Abstract

Aims *Primary*: To ascertain how many New Zealand (NZ) children are being injured or killed as the result of all-terrain vehicle (ATV) injuries and to define the nature and severity of their injuries. *Secondary*: to examine the effect of age, weight, helmet use, and ATV size on injury severity and to compare the demographics of injury in NZ to other countries.

Methods A retrospective review was undertaken of 643 cases of children less than 16 years old hospitalised between 2000–2006 due to possible ATV-related injury. New Zealand Health Information Statistics (NZHIS) identified the cases through discharge information, supplemented by a search of Auckland's Paediatric Intensive Care trauma database. Only confirmed ATV injuries were included.

Results: Records were unavailable for 150 cases (26%). There were 218 confirmed cases of ATV injury. Mechanisms of injury were: a fall from the ATV, 105 cases (48%), a collision, 59 cases (31%), rolling 31 cases (14%). Mean age was 9.9 years (SD 3.9) with 133 (61%) under 12 years, and 32 (15%) 5 years and under. The child was the driver in 116 cases (53%) and the passenger in 61 cases (28%). Male to female ratio was 2:1. Mean injury severity score was 7.9 (SD 5.2). Median (IQR) length of stay was 2 days (1–4). Helmet use not stated in 62%, with only 30 cases (14%) identified as wearing helmets. The majority of injuries were orthopaedic, soft tissue injuries and head injuries. Multiple injuries occurred in 74 cases (34%). One hundred and eleven children (51%) required a general anaesthetic. Seventeen (7.8%) children required admission to intensive care. Six (2.8%) children were left with a permanent disability. Sixteen children died. There was no correlation between ISS and age or weight (Rho=-0.089, p=0.08 and Rho=0.49, p=0.79 respectively). The observed differences in ISS between helmet users and non-users, ATV drivers and passengers and size of ATV were not statistically significant. There was a trend towards reduced risk of head injury with helmet use RR =0.63 (95%CI 0.36-1.1), Chi-squared=3.09, p=0.09. The mean age of injured NZ children was lower than other countries and length of hospital stay was shorter. Gender distribution, injury type, and severity were similar to elsewhere.

Conclusions ATVs are potentially lethal and have the capacity to inflict significant harm. It is clear that it is not appropriate for a young child to ride an adult sized ATV due to the risk of serious injury and death. Public debate is needed as to whether education or legislation is the answer.

Several high profile child deaths in New Zealand (NZ) were caused by all-terrain vehicle (ATV) accidents but there is little data on the use of ATVs by NZ children or the nature and extent of the injuries caused. The few studies that do exist are

hampered by inability to identify data separate from general farm bikes and off-road motorbikes. They do suggest however that children are riding adult- sized ATVs. For instance, a 1993 survey of Southland farmers found over half the ATVs in use were operated by children with the permission of the owner.[1] In 2004 a safety trainer informally polled students at safety days that he held at rural schools. He found from 12 rural schools with an average roll of 50 children at each, only 5 or 6 children had not ridden an ATV.[2]

The primary objective of this study is to determine the nature and severity of ATV injuries in NZ children and secondarily, the compare injury severity scores in: helmet users and non-users, ATV drivers and passengers, riders of adult and child-sized ATVs. The effect of age and weight on injury severity will be examined, as will injury demographics and patterns in other countries.

Death by injury is the leading cause of death of children in developed countries. NZ children find themselves close to the bottom of a league table of rich countries for child death by injury—22nd out of 26 countries. Indeed, NZ children have an annual mortality rate of 13.7 per 100,000 compared to 9.5 per 100,000 in Australia and 6.1 per 100,000 in the UK. [3] It is not known to what extent ATVs contribute to death and injury in NZ children.

Overseas data show that children are more likely to be killed and injured than adults riding ATVs[4,5] and are also likely to be more severely injured.[6,7] As more ATVs are sold and ATVs become larger and more , the number of children and adults being injured or killed in the US continues to rise.[4] Drivers under 16 years old are 2.5 times more likely to be injured on ATVs than drivers 16–34 and 4.5 times more likely to be injured than drivers aged 35–54.[5] Thirty percent of deaths associated with ATV injuries occurred in those under 16 years old.[4]

Injuries sustained riding an ATV are often multiple and serious.[6,8–16] Injuries sustained riding an ATV are similar to or more severe than those due to motorbike accidents (on or off road) and car crashes and are more severe than those sustained as a result of bicycle accidents.[17–21] A child injured while riding an ATV is 6 times more likely to require hospitalisation and 12 times more likely to die than a child injured riding a bicycle.[22]

Head injuries are the most common cause of death.[6,10,15,16,23–25] The majority of studies suggest helmet use is protective against head injuries or in at least reducing the severity of the head injury.[6,16,25-27]

What is an ATV?

ATVs—also known as quad bikes or farm bikes—are motorised vehicles with 4 large, low-pressure tyres designed for off-road use. ATVs vary in size and power with engine sizes ranging from 50cc–700cc, and weigh up to 500kg with most 4-wheel ATVs being in the 240–280kg range.[28–30] Most ATVs have a solid rear axle (i.e. no rear differential), a motorbike style seat that is straddled, and motorbike style controls on the handlebars. An adult-sized ATV is one with an engine size of greater than 90cc. Three-wheeled ATVs are no longer sold due to safety concerns but it is not known how many remain in use in NZ.

Why is it hard for children under 16 to safely control an ATV?

Although they appear easy to ride and handle, riding an ATV requires the same or greater skill judgement and experience as for driving a car. ATVs are heavy, powerful machines and many accidents occur through loss of driver control.[31]

ATVs also appear to be stable vehicles but in fact have a high centre of gravity, a short wheel base and a narrow track width which make the vehicle inherently unstable, though the 4-wheel ATV is more stable than the 3-wheel ATV.

Several size and developmental factors prevent a child from driving an ATV with the same control as an adult. ATVs demand an active riding technique, where rider movement, strength and weight shifting are required to ensure stability and control. The active riding technique is needed to be able to effectively turn the vehicle round corners due to the lack of rear differential and to prevent vehicle rollover on uneven terrain and slopes. [28,31]

Children often lack the strength or weight to effectively handle an ATV and do not have sufficient mass to act as a counterweight especially on slopes. Some have trouble reaching the controls. Most children have not yet developed the skills and judgement to safely operate or ride as a passenger on an ATV.[28]

Current New Zealand Guidelines

There is no legislation governing the off-road use of ATVs. Current guidelines produced by ACC, Occupational Health and Safety, and the Land Transport Safety Authority recommend that children under 16 years of age never operate an adult-sized ATV. [28, 31, 32]

The guidelines suggest that 12–15 year olds may operate an adult-sized ATV under strict conditions such as the following: the young person must have the size and strength to safely operate the ATV, they must be trained in the use of the ATV, they must wear a helmet and sturdy boots at all times, they never carry passengers, implements or loads, they have speed limits and "no go" areas for difficult terrain, and they are supervised to make sure they stay within their limits.

Children under 12 years should never operate an adult-sized ATV. If a child under 12 is to operate an ATV the engine size should match the child's age, as follows: 6–11 years under 70cc and 12–15 years 70–90cc. There are no vehicles considered suitable for a child under the age of 6. Nor is there any conclusive evidence to suggest that children riding smaller-sized ATVs have fewer accidents or less severe injuries than those on adult-sized ATVs.

Passengers should never be carried on an ATV. Most ATVs are not designed to carry passengers. Many victims of ATV accidents are passengers, often young children riding behind or in front of a parent. ATVs are equipped with large seats to allow the driver to shift weight to control the vehicle, not to carry other people. Passengers restrict the driver's mobility and add weight to an ATV, raising the centre of gravity, making it harder to control and more prone to tipping over.

There have been numerous calls overseas for legislation to prohibit the use of adult sized (>90cc) ATVs by those under 16 years of age.[26,29,33–35] US and Canadian-based

research shows that though ATV legislation such as restricting the use of adult-sized ATVs to those older than 16 years old or mandatory helmet use is widely ignored, states which had some form of legislation had lower rates of death and injury.[13,16,23,25,36]

Methods

Data collection—Data collected by the New Zealand Health Information Service (NZHIS) from 2000–2006 identified 643 cases of children under 16 years who were hospitalised as the result of an injury coded under V86—ATV or other motorised vehicle designed primarily for off-road use. Having obtained multiregional ethics committee approval, information was released from NZHIS, providing the national health identifier (NHI), dates of admission and discharge, ethnicity, and the district health board (DHB) of the hospital.

Copies of the relevant admissions from DHBs around the country were then requested through the clinical records department of Auckland Hospital. Only those cases that were positively identified as an injury sustained while riding a 3 or 4-wheeled ATV were included.

This was supplemented by data from Starship Hospital's Paediatric Intensive Care Unit's (PICU) database (Appendix 1). NZHIS also provided limited data on deaths due to ATV injury from 2000 to 2006.

Data was collected on demographics, weight of patient, site of accident, accident mechanism and helmet use, whether the injured child was the driver or the passenger, presence of adult supervision, ATV size and type, length of hospital stay, the need for admission to intensive care, the need for surgical intervention, and the nature of the injuries sustained. Injury severity score was calculated in the standard manner using the Abbreviated Injury Scale from the Association for the Advancement of Automotive Medicine (1998 Update).

Statistics—Descriptive statistics and charts were used to display demographic data. Means (SD), medians (IQR), and proportions (95%CI) were calculated where appropriate. The frequency distributions of quantitative variables were examined to determine Normality. Non-parametric methods (Spearman's Rank Order Correlation and Mann-Whitney U Tests) were used to analyse non-Normally distributed variables. Chi-squared or Fisher's exact tests were used where appropriate to analyse categorical data. Proportions (95%CI) were calculated using GraphPad Software California, USA and OpenEpi version 2.3. All other analysis was done using StatView© version 5.0 (SAS Institute Inc., North Carolina, USA). All analyses were 2-tailed and the significance level was <0.05.

Results

From a total of 643 discharges with a code of V86, 218 were positively identified as injuries sustained while riding a 3 or 4-wheeled ATV. Fifty-seven were multiple admissions or duplicated admissions for the same patient. Only the first admission was entered in the database. Confirmed ATV injuries made up 50% of available notes.

643 discharges coded V86

- 57 multiple admissions or duplicated admissions.
- 150 sets of notes unavailable (26%).
- 436 sets of notes reviewed.
- 218 excluded as non-ATV related.

218 confirmed ATV-related injuries

Injury demographics—Demographic details of injured children are set out in Table 1.

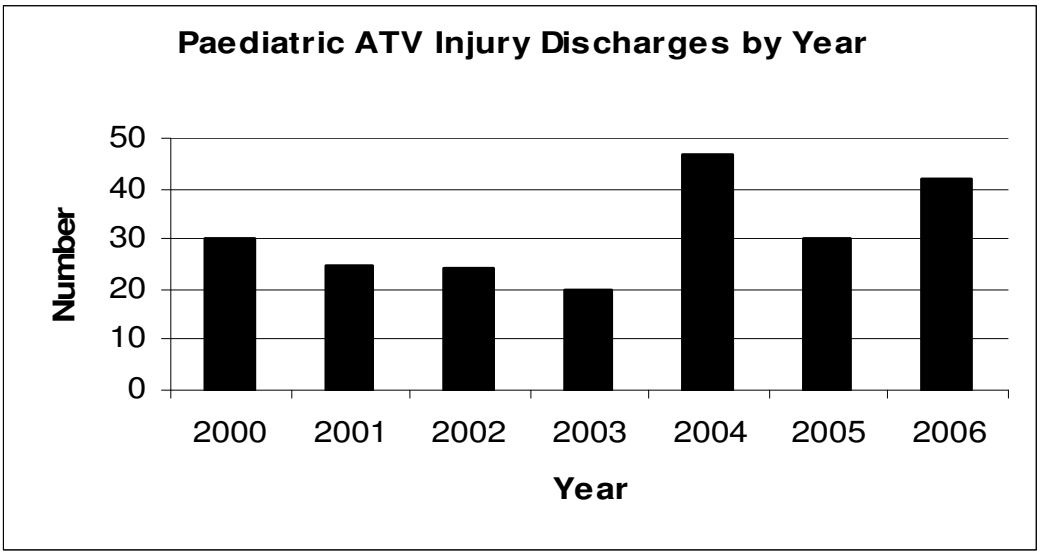
Table 1. Child, Injury and ATV demographics

Variable		Value	%	95 % CI
Age	Mean (SD)	9.8 (3.9)		
	12–15 yr	85	39.0	32.8–45.6
	5–12 yr	101	46.3	39.8–53
	≤5 yr	32	14.7	10.6–20
Weight (n=137)	Mean (SD)	35.9 (17.3)		
	≤50 kg	113	82.5	75.2-88
Gender	Boys	149	68.4	61.9–74.2
	Girls	69	31.7	25.8–38.1
Ethnicity	NZ European	142	65.4	58.6–71.2
	Māori	58	26.7	21.2–32.9
	Other European	5	2.3	0.8–5.41
	Pacific Islander	3	1.4	0–4.2
	Indian	1	0.5	0–2.8
	Not recorded	7	3.2	1.4–6.6
Length of Hospital Stay	Mean (SD)	3.1 (5.4)	Median (IQR)	2 (1–3)
Injury Severity Score	Mean (SD)	7.9 (5.2)	Median (IQR)	9 (4–9)
	< 10	170	78	72.4–83.3
	10–15	31	14.2	10.2–19.6
	>15	17	7.8	4.9–12.3
ICU admissions	PICU	6	2.8	1.1–6
	Adult ICU	11	5.1	2.7–8.9
General anaesthetic		111	50.9	44.3–57.5
Disposition	Home	216	99.1	96.5–100
	Rehabilitation centre	2	0.9%	0–3.5
	Permanent disability	7	3.2	1.4–6.6
Deaths*		16	6.8	4.2–10.9
ATV Type	4 wheels	205	94	88.9–95.9
	3 wheels	13	6	3.4–10
ATV Size **	Adult	23	54.8	39.9–68.8
(recorded n=42, 19%)	Child	19	45.2	31.2–60
ATV Use **	Driver	116	65.5	58.3–72.2
(recorded n=177, 81%)	Passenger	61	34.5	27.9–41.4
Helmet Worn **	Yes	30	36.1	26.6–46.9
(recorded n=83, 38%)	No	53	63.9	53.1–73.4
Adult supervising **	Yes	28	50.9	36.6–61.7
(recorded n=55, 25%)	No	27	49.1	35–60

ATV = All Terrain Vehicle, PICU = Paediatric Intensive Care Unit, ICU = mixed or adult Intensive Care Unit, NZ = New Zealand; SD = standard deviation, IQR = Interquartile range, kg = kilogram, * deaths expressed as % of 234 injured children, ** expressed as % of number of cases where this was documented.

There is an increase over time in the number of children discharged with confirmed ATV injuries, however, the number of unobtainable notes and the short time period make it difficult to draw any firm conclusions (Figure 1).

Figure 1. Children discharged with ATV injury by year



ATV=All Terrain Vehicle

Figure 2 shows the mechanism of injuries and figure 3 shows where the injuries occurred.

Figure 2. Mechanism of injury

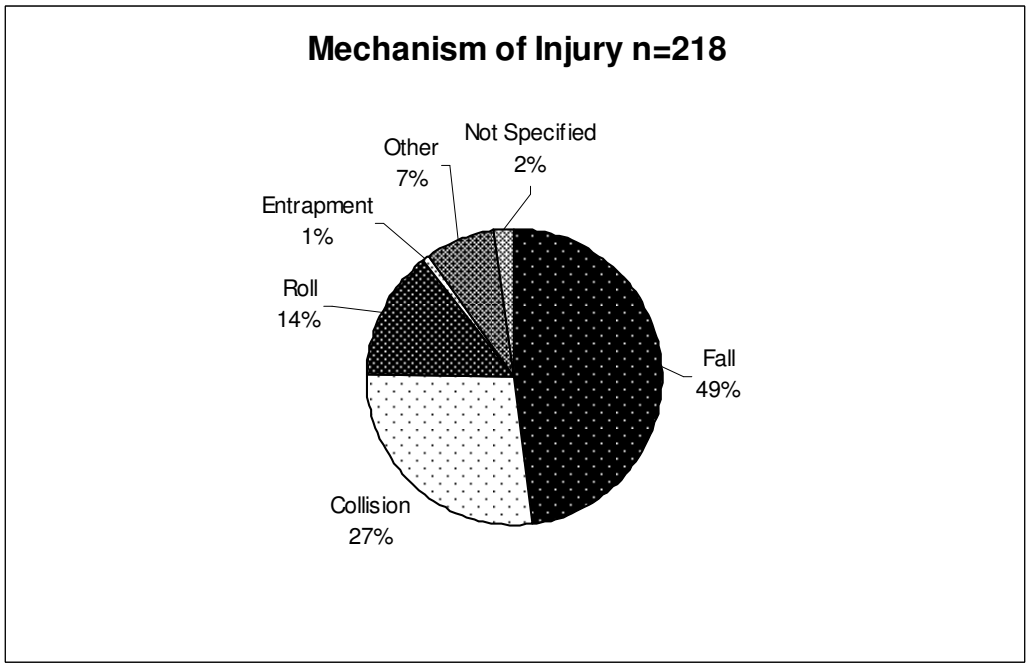
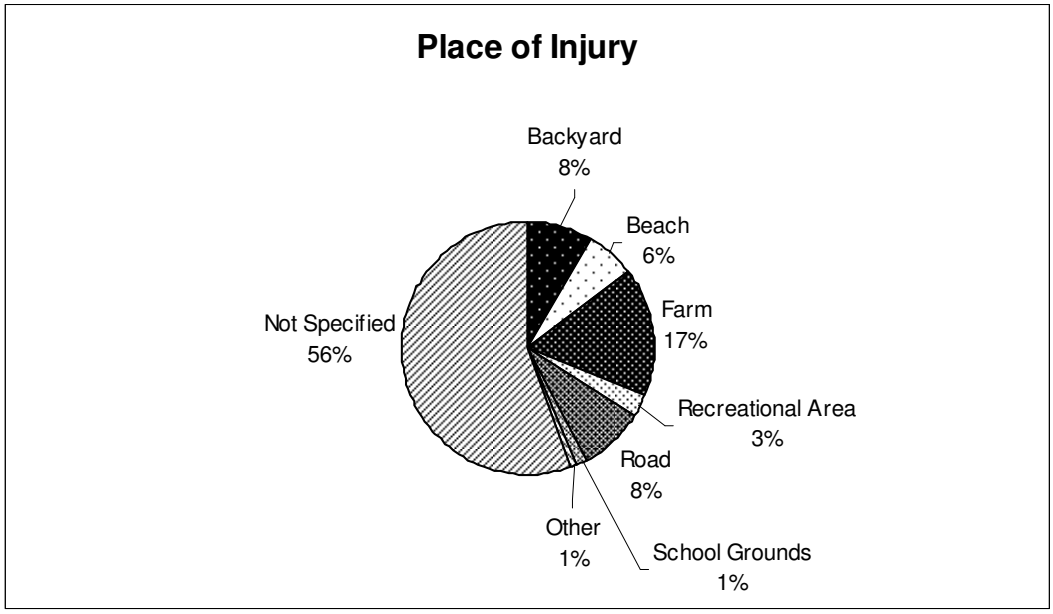


Figure 3. Places where ATV injuries occurred

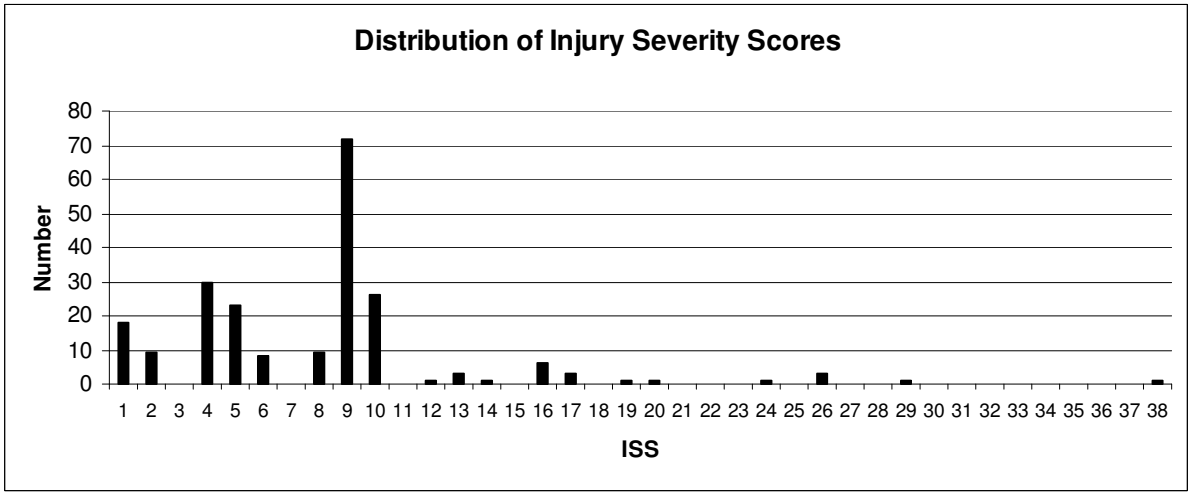


ATV=All Terrain Vehicle.

Injury pattern and severity

Figure 4 shows the range and distribution of injury severity scores.

Figure 4. Injury severity score



ISS = Injury Severity Score (sum of squares of three most severely injured body regions)

Orthopaedic, soft tissue, head, and facial injuries were the most frequent injuries. Seventy-four children (33.9%, 95%CI 28–40%) had multiple injuries involving more than one body part (Table 2).

Table 2. Injury pattern*

Injury type	Number	%	95% CI
Fractures/dislocations	126	57.7	50.7–63.7
Soft tissue	121	55.5	48.9–62
Head	61	27.9	23.3–35.3
Face	51	23.6	18.4-29.8
Thorax	7	3.2	1.4–6.6
Abdomen	17	7.8	4.9–12.2
Spine	10	4.6	2.1–7.9
Pelvic fractures	3	1.4	0–4.3

*Total > 100% due to multiple injuries

The most common orthopaedic injuries were closed fracture of the radius ± ulna and fracture of the tibia ± fibula. There were 11 compound fractures (6 of these were compound fractures of the tibia and/or fibula), 19 fractured femurs (in 2 cases bilateral fractured femurs) and a dislocated hip associated with acetabular fractures.

There was one case of a closed Lisfranc injury and another of compound fractures of the mid-foot ultimately requiring a below knee amputation. Two patients had tendon injuries of the hand and forearm requiring surgical repair.

Soft tissue injuries were frequent, comprising lacerations, contusions, abrasions and limb sprains. Fifty-six (26%, 95%CI 20–32%) sustained lacerations which required wound closure and 41 of these (73%, 95%CI 60–83%) had their wound closed under a general anaesthetic.

Some of the soft tissue injuries were severe; including 2 de-gloving injuries of the hand with partial amputation of digits, 6 deep thigh lacerations from handlebars injuries, an open pneumothorax, 11 compound fractures, and a burn from an exhaust which required skin-grafting.

Sixty-one patients sustained head injuries (28%, 95%CI 23–39%), of which 52 (85%, 95%CI 19–31%) were minor head injuries. Concussion was diagnosed in 49 (78%, 95% CI 66–86.4%). Thirty–three children were admitted primarily for neurological observation. Three had moderate and 6 had severe head injuries. There were 10 children with skull fractures. Amongst the moderate to severe head injuries were 2 extradural haemorrhages, 4 children with intracerebral contusions, 2 with intracerebral haemorrhages, 3 with deep white matter or basal ganglia petechiae, 2 with diffuse axonal injury, and one who suffered a hypoxic encephalopathy when trapped beneath the ATV for 20 minutes.

All head injuries were managed conservatively. Only one child required neurosurgical intervention to elevate and wash out a compound, depressed skull fracture. All 6 patients admitted to PICU had a head injury.

There were 51 patients with facial injuries (23%, 95%CI 18–29%). Ten patients had facial fractures, 5 of whom had other soft tissue facial injuries. 26 patients sustained facial lacerations (excluding scalp) and another 19 sustained facial contusions or abrasions. Four children required surgery for facial fractures—3 maxillary and 1

mandibular. There were 7 children with chest injuries, 5 cases with pulmonary contusions and 4 with pneumothoraces. One child had multiple rib fractures.

Abdominal injuries were predominately contusions of the abdominal wall with a small number being admitted for observation due to abdominal pain but with normal imaging with ultrasound or CT scan. There were two cases of a liver laceration and two of splenic laceration, all were managed conservatively. There were two cases of microscopic haematuria with flank pain but no renal abnormalities on imaging.

Spinal injuries were infrequent. There were eight children with cervical sprains two of which resulted in the child wearing a Philadelphia collar for 2 weeks. Two children had stable fractures of the thoracic or lumbar spines.

Secondary outcomes—There was no correlation between ISS and age or weight (Rho = -0.089, P=0.08 and Rho = 0.49, p=0.79 respectively). The observed differences in ISS between helmet users and non-users, ATV drivers and passengers and size of ATV (Table 3) were not statistically significant. There was a non-significant trend towards reduced risk of head injury with helmet use RR=0.63 (95%CI 0.36–1.1), chi-squared=3.09, p=0.09. The large proportion of missing data for helmet use and ATV Size mean these results should be interpreted with caution.

Table 3. Effect of helmet use, position on ATV, and ATV size on injury severity

Variable n=212		n	Injury Severity Score		P**
			Mean(SD)*	Median (IQR)	
Helmet Use	Yes	30	7.6 (5.0)	8 (4–10)	0.72
n=83	No	53	8.6 (6.1)	9 (5–10)	
ATV Use	Driver	116	7.8 (4.7)	9 (4–9)	0.44
n=177	Passenger	61	8.3 (6.3)	9 (5–10)	
ATV Size	Child	19	6 (3.2)	5 (4–9)	0.16
n=42	Adult	23	9.8 (7.2)	9 (4–10)	

*Although Injury Severity Score is not Normally distributed and strictly speaking an ordinal variable, means (SD) are also presented by to facilitate comparisons with other studies where it is treated as a continuous variable.
**Mann Whitney U Test. ATV = All Terrain Vehicle, SD = standard deviation, IQR = interquartile range

International comparisons—New Zealand's experience with children and ATVs is broadly similar to that in the US and Canada, where most studies have been based, with similar ISS, helmet use, proportion of males injured and injury pattern. Our study appeared to show a slightly younger age of injured children and shorter length of stay than international studies which may be due to the fact that the current study looked at all hospital admissions whereas overseas studies looked predominantly at tertiary paediatric referral centre admissions (Appendix 2).

Deaths—There was limited information regarding the deaths of 16 children (<16 years old) killed in an accident involving an ATV between 2000 and 2006. At least 3 of these children died in hospital. The cause of death is not recorded in NZHIS data, however the mechanism of the accident is known for most. Twelve of the children were NZ Europeans, two were Māori, one was "other European" and one had no ethnicity recorded (Table 4).

Table 4. Paediatric ATV-related deaths 2000–2006

Year	Age	Mechanism
2000	2	Passenger on 4W ATV with 3 adults, flipped going up steep hill
	4	Passenger on 4W ATV with loaded trailer, overturned & rolled off steep bank, trapping child
	8	Riding 4W ATV, collided with barrier around tree, head & chest injuries
2001	12	Driving 4W ATV
	14	Driving 4W ATV, overturned, trapped child under ATV, sustained cervical spine, chest, liver & splenic injuries
	11	Poorly maintained 4W ATV with overloaded trailer, rolled, trapped child under ATV
	11	Attempted to jump over top of a ridge, fell from 2m, sustained head injuries
	7	No details given
2002	14	4W ATV flipped and trapped child under it
	12	4W ATV flipped on farm track
	9	4W ATV flipped and trapped child under it
	14	4W ATV flipped and trapped child under it
	14	Drowned after falling from 4W ATV trying to cross a flooded ford
2004	12	Riding 4W ATV on farm, ATV rolled and pinned him by the neck
2005	4	Child was driving the ATV
2006	9	No details given

Discussion

This study represents the first attempt to ascertain the number and severity of childhood injuries caused by ATVs in New Zealand. A clear pattern of injury has emerged, which is similar to that reported in the international literature, with orthopaedic, soft tissue and head and facial injuries predominating.

This study highlights a number of areas of concern. The current NZ guidelines recommend that children under 12 years never ride an adult-sized ATV. In this study over half of children injured were under 12 years old with a significant number aged 5 and under.

Few children under 12 were confirmed to be riding a child-sized ATV. Guidelines also state that ATVs should never carry passengers; however one quarter of the patients in this study were injured as passengers and most of the passengers were under 12 years old. If current safety guidelines had been followed two thirds of the injuries documented in this study may not have happened.

It is noteworthy that there was a potentially clinically important difference in injury severity for child sized versus adult sized ATVs which did not reach statistical significance due to the small number of cases where ATV size was recorded. It is logical to assume that child sized ATVs would be safer as the mass of the child will therefore better match that of the vehicle. It is, however, also possible that this effect becomes less important than developmental limitations with reducing age and demands further study.

The quality of the written notes was often poor and sometimes gave no indication of mechanism of injury. Helmet use was poorly documented, even in patients presenting with head and facial injuries.

US and Canadian attempts to legislate or educate regarding safe ATV use have proved to have limited, though some, effect. In NZ, rural children in particular are encouraged to take part in life on the farm or are carried as passengers while their parents go about their work. There is an attitude of "she'll be right" and of fostering independence and self reliance in farm kids. In addition ATVs are increasingly used for recreational activities outside the farm setting when they appear no less dangerous.

Limitations of this study—This is a retrospective review that relies on accurate coding to correctly identify all ATV related injuries. It is possible that injuries due to ATVs have been missed due to incorrect discharge coding. Accurate coding of course relies on there being an adequate description of the incident in the clinical notes. This study may underestimate the number of ATV related injuries in children due to difficulties obtaining all potentially relevant clinical notes.

Extracting data from clinical notes similarly depends on their detail and accuracy. There is also the possibility of human error in the extraction and data entry process. This study only reviewed ATV injuries that resulted in hospitalisation so is likely to be an underestimate of the true burden of ATV-related injury in New Zealand's children.

Recommendations—Public debate is needed. Is the current high level of child death and injury in this country acceptable to New Zealanders? Use of ATVs by children is manifestly risky. While children and adolescents need to learn how to assess risk and gain strength and coordination by partaking in activities that provide such challenges, there are significant size and developmental realities that children face that adult operators do not. It is clear that it is not appropriate to allow a young child to ride an adult sized ATV due to the potential for serious injury and death.

Organisations such as ACC, Occupational Health and Safety and the Land Transport Authority produce widely available guidelines and instructions on safe use of an ATV. These guidelines appear a reasonable compromise on the US and Canadian positions that children under 16 years should never ride an adult sized ATV, but are clearly widely ignored. It is possible that many parents are unaware of the dangers and at the very least guidelines should be made available at the point of purchase. Is further public awareness and education the answer or is legislation required?

Enforcement particularly in a rural setting might be a challenge and may have to rely instead on prosecution after a child is injured. Legislation at least would inform and set a standard both to the point of sale and to parents and may be required to protect children from life threatening injuries.

Health care professionals that encounter children injured as a result of an ATV accident should be mindful of the potential for severe injury and assess the child thoroughly. Much improvement in the detail of clinical notes particularly injury mechanism and helmet use is required. Health care professionals are in a unique position to advocate for child safety with regard to ATV injured children and need to embrace this responsibility.

International experience shows a marked reduction in head injury with helmet use. In NZ a specific helmet has been designed for ATV use by adults. We recommend all children on an ATV wear a full face motorbike style helmet, given the high rate of head and facial injuries.

In conclusion, ATVs are potentially lethal and have the capacity to inflict significant harm. It is clear that it is not appropriate for a young child to ride an adult-sized ATV due to the risk of serious injury and death.

Public debate is needed as to whether education or legislation is the answer.

Competing interests: None known.

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See following Appendices

Appendix 1. Children admitted to PICU with an ATV injury: 1997–2008

Year	Age & gender	Mechanism	Helmet	Injuries	Intervention	Outcome
1997	10 male	Passenger on 4W ATV driven by cousin into a ditch, fell off, hitting head on roll bar	no	Initial GCS 14, skull # with CSF leak, orbital and nasal #, traumatic maculopathy left eye, eyelid laceration, facial contusions	? sutures, observation, later left eye vitrectomy, MUA nasal #	3 days in hospital, < 24 hrs in PICU. Discharged home, uncertain if permanently decreased acuity left eye
1998	12 male	Driver of 4W ATV, hit fence in school grounds	no	Initial GCS 8, skull#, large subdural haemorrhage, with smaller extradural component + midline shift, bifrontal cerebral contusions, forehead and scalp contusions	Ventilated, craniectomy for evacuation of haematoma & ICP monitor insertion, later second craniectomy for repeat evacuation haematoma & resection contused temporal lobe	15 days in hospital, 6 in PICU, discharged to rehab unit, decreased higher functions, partial left homonymous hemianopia
2000	9 male	Driver 4W ATV, hit pole, found unconscious with ATV on top of him	no	Initial GCS 6, right intracerebral haemorrhage, bilateral closed femur #s, hip contusions	Ventilated, head injury managed medically, ORIF left femur, EXFIX right femur	10 days in hospital, 4 days in PICU, discharged to rehab in regional hospital, higher cognitive function defects, left sided weakness, sensory changes & neglect
2002	3 male	Unspecified if driver or passenger, fell off back 4W ATV, back wheels ran over his legs, head hit road, low speed	no	Initial GCS 6, diffuse axonal injury, petechial haemorrhages in basal ganglia and left temporal lobe, 3rd nerve palsy	Ventilated, head injury managed medically, tracheostomy, later required laryngeal reconstruction for severe sub-glottic stenosis, later had eye surgery to correct squint	35 days in hospital, 13 days in PICU, discharged to rehab centre, gradually resolving bilateral motor deficits & dystonia
2004	11 male	Driver 4W ATV on gravel road, 30kph, served to avoid car, ATV went into ditch, trapped under ATV for 20 mins	yes	Initial GCS 4, small frontoparietal contusions, hypoxic encephalopathy, unilateral pulmonary contusions, multiple abrasions & contusions, scalp laceration	Ventilated, head injury managed medically, scalp laceration sutured	5 days in hospital, 2 days in PICU, discharged home with mild left sided weakness and higher cognitive function deficits which resolved over the next 12 months
2004	14	Passenger on 4W ATV, crossed road and hit by	no	Initial GCS 10, left base of skull #, small cerebral contusions, pneumocephalus, scalp	Ventilated, head injury managed medically	5 days in Auckland hospital, 1 day in PICU, Discharged to regional

	Male	car at approx 80kph		contusions, microscopic haematuria but normal CT kidneys, closed # R 2nd metacarpal		hospital, unknown if any permanent deficit
2004	6 Male	Passenger on 4W ATV, hit by 4WD vehicle from behind	no	Initial GCS 3, left frontal contusion & intracerebral haemorrhage, lacerations to forehead and scalp, left femur #	Ventilated, head injury managed medically, ORIF & hip spika L femur, lacerations sutured	18 days in Auckland Hospital, 3 days in PICU, discharged to regional hospital, no permanent deficits
2006	2 Male	Driver on child-sized (50cc) 4W ATV, briefly unsupervised, found unconscious under ATV in backyard	yes	Initial GCS 6, CT head normal, abrasions to chest & abdomen	Ventilated, head injury managed medically	6 days in Auckland Hospital, <24hrs in PICU, discharged to regional hospital, no reports of any long term sequalae
2007	4 Male	Driver of 4W ATV, unwitnessed fall from ATV	yes	GCS 15, presented in respiratory distress, ruptured right main bronchus, unilateral pulmonary contusions, stable #s C6-T3, multiple abrasions and contusions	RSI & right chest drain in ED, continuous air leak, taken to theatre for thoracotomy & repair ruptured right main bronchus, spinal #s managed conservatively	6 days in Auckland Hospital, <24hrs in PICU, full recovery
2007	14 Male	Driver of 4W ATV, rolled 6m down embankment	N/S	Initial GCS 14, #/dislocation T9 on T10 with complete paraplegia from level T8, unilateral pulmonary contusion, pleural effusion	Ventilated <24hrs, spinal cord decompression, spinal fusion T7-12, chest drain	26 days in Auckland Hospital, 3 days in PICU, permanent T8 paraplegia, discharged to spinal unit
2008	6 Male	Driver of child-sized 3W ATV, rode into tree	no	GCS 7, depressed skull # extending into L orbit, haemorrhagic contusions L frontal lobe, intraventricular haemorrhage, traumatic neuropathy L optic nerve, massive scalp laceration with avulsion temporalis muscle	Ventilated, craniectomy, elevation & debridement skull#, ICP monitor, medical management head injury	? stay in Auckland Hospital, 10 days in PICU, developed diabetes insipidus, discharged to rehab centre, R sided hemiparesis, decreased cognitive function

Appendix 2. International comparisons

Year published & author	Years studied	Group studied	Mean age	Mean ISS	Mean length of stay	Male	Wearing helmet	ICU	Deaths	Injury pattern
2007 Kirkpatrick10	2001-2007	73 children < 16 yrs, Level I trauma centre, US	9.9	10.3	n/s	n/s	n/s	n/s	4 due to head injuries	45% head 29% upper limb 21% lower limb 27% face 15% abdomen 14% chest 8% pelvis 5% spine
2007 Kute27	1995-2005	238 children <16 yrs, Level I Paediatric Trauma Centre, US	11.4 ± 3.6	7.3 ±5.6	4.3 ± 4.0	70%	16%	18%	none	32% lower limb 25% upper limb 25% skull or face # 27% soft tissue 18% closed head injury 13% abdomen
2006 Prigozen12	2001-2004	26 children with craniofacial injuries (children not defined)	13.1	n/s	4.6 ± 5	65%	8%	36%	1	77% skull or face # 65% soft tissue facial injuries 35% closed head injuries
2006 Yanchar20	1993-2002	130 children <16 yrs at tertiary paediatric centre, Canada	n/s	n/s	8.3 (SD 2.5-14.2)	n/s	n/s	31%		48% fractures/dislocations 40% cuts & bruises 18% deep soft tissue injury 10% head injury 4% internal organ injury 1% facial injury
2006 Gittleman36	1995-2001	285 children <16 yrs from 7 US paediatric trauma centres	11.1	9.2	n/s	76%	28%	n/s	2	57% multiple injuries 31% fractures 23% head injury 22% soft tissue injury
2006	2001-2004	50 children, aged 3-	Median 13	n/s	6 (range 1-47)	50%	16%	14%		54% head injury

Su13		17 years, Children's Hospital, Canada								28% orthopaedic injury 14% facial # 4% abdomen
2006 Alawi37	1998-2003	17 children aged 8-17 yrs **with ISS>12**,children's hospital, Canada	13.7	22.8	9.7	82%	65%	n/s	none	76% fractures 47% splenic lacerations 35% head injury
2005 Kelleher38	1993-2002	184 children (not defined) at paediatric hospital, US	11.5 ± 3.9	10 ± 8.7	5 ± 12 Median 2	71%	35%	19%	3	68% multiple injuries 50% required surgery 51% orthopaedic injury 50% soft tissue 37% craniofacial 23% thorax/abdomen
2004 Murphy16	1990-2002	92 children < 16 yrs, tertiary paediatric trauma centre, Canada	12.1	7 ± 6.6 (range 1-35)	7.5 ± 14.8 Median 3	79%	40%	18%	2	45% multiple injuries 72% orthopaedic 29% soft tissue 24% head & face 13% chest & abdomen
2001 Cvijanovich14	1992-1996	130 children < 16 yrs, US	11.2 ± 3.6	8.0 ± 6.0	Median 2 Range 0-43	73%	n/s	n/s	1	60% orthopaedic 60% soft tissue 22% head 5% abdomen 3% chest
1998 Lister39	1991-1995	218 children aged 2-16 yrs	12.4	8.76 ± 6.0	4.3 ± 5.2 Range 0-29	75%	12%	19%	4	38% required surgery 53% orthopaedic 40% head 35% face 25% abdomen 20% chest 8% spine