SUPPLEMENTAL REPORT

INVESTIGATION AND ANALYSIS OF QUAD BIKE AND SIDE BY SIDE VEHICLE (SSV) FATALITIES AND INJURIES

by

Professor Raphael Grzebieta,

Adjunct Associate Professor George Rechnitzer

Dr. Andrew McIntosh

Dr. Rebecca Mitchell

Dr. Declan Patton

Mr. Keith Simmons

TARS, University of New South Wales

for

THE WORKCOVER AUTHORITY OF NEW SOUTH WALES

92-100 Donnison Street, Gosford, New South Wales 2250.

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Contents

1 Executive Summary

This report should be read in conjunction with the Report 1-2013, Part 1: Static Stability Test Results, and in particular the introductory chapters.

The Heads of Workplace Safety Authorities (HWSA) identified in 2011 Quad bike safety to be a major issue on farms in Australia and New Zealand. They stated that "*In Australia, more than 64 per cent of quad bike deaths occur on farms and in the last 10 years there have been 130 quad bike fatalities across the country. In New Zealand, five people (on average) are killed on farms and over 845 injuries reported each year.*"

This supplemental report presents the results from the examination and analysis of most of those Australian fatalities and also of US fatality and serious injury data relating to Quad bikes and Side by Side Vehicles (SSVs). It forms an integral part of the Quad bike Performance Project funded by the WorkCover Authority of New South Wales (Australia) with some additional funding provided by the Australian Consumer and Competition Commission (ACCC). The Quad Bike Performance Project commenced in September 2012 and the last series of testing (Rollover Crashworthiness) was completed by around June 2014.

The Quad Bike Performance Project (QBPP) is aimed at improving the safety of Quad bikes, in the workplace and farm environment by critically evaluating, conducting research, and carrying out testing, to identify the engineering and design features required for improved vehicle Static Stability, Dynamic Handling and Rollover Crashworthiness including operator protective devices and accessories.

It is recommended that this is best done through the application of a Quad bike and Side by Side Vehicle Star Rating system (ATVAP: Australian Terrain Vehicle Assessment Program). Such a program would inform consumers purchasing vehicles or accessories for use in the workplace. The Star Rating system is intended to provide 'a safety rating' in that vehicles with higher star ratings will represent a lower risk of rollover and subsequent potential injury in the event of a rollover incident in the workplace environment based on the best currently available information.

It is hoped that ATVAP, if adopted, would provide similar benefits for consumers and workplace plant managers and plant controllers. The objective would be to introduce a robust, test based rating system, in order to provide workplace and consumer based incentives for informed, safer and appropriate vehicle purchase (highlighting 'Fit For Purpose' criteria), and at the same time generate corresponding incentives and competition amongst the Quad bike and SSV Industry for improved, safer designs and models.

The Quad bike Performance Project consists of three parts: Part 1 focusses on Static Stability; Part 2 focusses on Dynamic Handling Stability; and Part 3 focusses on Rollover Crashworthiness. There is also a Final Project Summary Report: Quad Bike Performance Project Test Results, Conclusions and Recommendations, which summarises all of the findings and presents the proposed ATVAP Star Rating. This Supplemental report (being one of the five reports) underpins all three Parts 1 to 3 and the Final Project Summary Report in that it provides the evidence required that justifying the various test protocols carried out and the proposed ATVAP Star Rating which ranks a vehicle's rollover static stability, dynamic handing and rollover crashworthiness.

This report focusses mainly on summarising Australian fatality and injury data. Also included in this report in the Attachments is: an analysis of US Consumer Product Safety Commission US data of fatal All-Terrain Vehicle (Quad bike) crashes; a literature review of various papers and reports providing information of mostly US ATV (Quad bike) fatalities and injuries; and recommendations for possible crashworthiness tests.

It should be noted that throughout this report the term 'Quad bike' is used to refer to those four wheeled vehicles which a rider straddles and uses a handle bar to operate similar to a motorcycle [Rechnitzer et al. (2012)]. These vehicle are denoted as ATVs in the United States of America (USA). A Side by Side vehicle (SSV) is a four wheel vehicle which is operated by sitting in the vehicle and using a steering wheel to turn the vehicle and peddles to brake and accelerate, similar to a road vehicle. Such vehicles are called Recreational Off Highway Vehicles (ROVs) or Utility Terrain Vehicles (UTVs) in the USA.

Quad bikes in Australia are also referred to as Quads. The Authors have a particular concern in the use of the additional descriptor 'bikes', which is the terminology commonly used to describe two wheel vehicles such as motorcycles and bicycles. Nevertheless, the term 'Quad bike' is used throughout all of our reports as it is the common term used by regulatory authorities. When two wheel vehicles are stationary on flat terrain they are inherently unstable unless supported by a propping device whereas a four wheel vehicle is stable on a flat terrain when stationary. The concern is that such stability infers the Quad bikes operate similar to road vehicles, and as a consequence, can infer similar static and dynamic stability characteristics to a car even when operated on all terrains. This can and has resulted in quite dangerous outcomes.

In the USA the term used to describe a Quad bike is All-Terrain Vehicle or ATV. However, this terminology can be confusing as it is sometimes mistakenly used around the world to include SSVs, ROVs or UTVs along with Quad bikes. For example in Sweden the term ATV represents all these forms of vehicles. In this report we shall use the terms Quad bike and SSV and distinguish between them.

2 Fatality Data

In regards to Australian fatal crashes, 141 fatalities were identified from the Australian National Coronial Information System (NCIS) dataset of fatalities that occurred over a period of twelve years (2000 to 2012), approximately 10 to 15 fatalities per annum.

The vehicles involved were almost all Quad bikes. Only five cases involving some form of SSV were found in the data. Full documentation of the closed cases was retrieved from State Coroners around Australia, investigated and key information noted and analysed. It is unclear whether the dominance of the Quad bikes in the data is because of exposure (higher number of Quad bikes and their usage) or because the static stability of the SSVs is much higher than Quad bikes. The rate of fatalities per 10,000 vehicles for both Quad bikes and SSVs needs to be established and monitored. Presently, the fatality rate for Quad bikes appears to be around 0.6 per 10,000 vehicles, higher than for road vehicles which is presently around 0.47 per 10,000 vehicles. It is not possible to establish the rate of fatalities per 10,000 vehicles for SSVs. This is because data on the number of SSVs in Australia has not been available from the Federal Chamber of Automotive Industries (FCAI) or elsewhere.

86% of deaths were male where the mean height and body mass for all cases in the age group 15 to 74 years were 1.75 m and 81 kg, respectively.

After review of the 141 cases by McIntosh and Patton, 32 cases were identified as involving public road crashes and other vehicle types such as sand buggies. These were excluded in their analysis of the remaining 109 cases (Attachment 1). There were 106 Quad bikes, two SSVs and one six wheel vehicle with a straddle seat in their remaining sample of 109 cases.

Approximately half (54) of the 109 fatalities were related to workplace activity, specifically farming (53), and half (55) to recreational activity.[1] Moreover, farms were the location for approximately three quarters (82) of all the 109 incidents.

In work related cases, 76% of the people killed were in the age group 15 to 74 years and 42% were older than 65 years. The age distribution for work related fatalities was skewed to the older age groups as is obvious in Figure 1.

The vehicle rolled in 77 of the 109 cases (70.6%). Forty six (46) of the 54 (85.2%) work related crashes involved a rollover compared to 31 of the 55 (56.4%) recreational crashes.

Where the roll direction was noted, there were 11 (10.1%) forward rolls, 32 (29.4%) lateral rolls, 5 (4.6%) rearward rolls. In 29 (26.6%) cases rollover was noted but the roll direction was unknown.

[1] **Definitions of work and recreational cases.** These are based on reviewing the Coronial case files and determining the activity being undertaken by the vehicle rider/ driver at the time of the fatal incident. That is whether the activity was work related in some way or recreational related. In regard to work related activities the relevant activities are listed in Appendix B. Recreational is defined as per the Oxford Dictionary "Relating to or denoting activity done for enjoyment when one is not working".

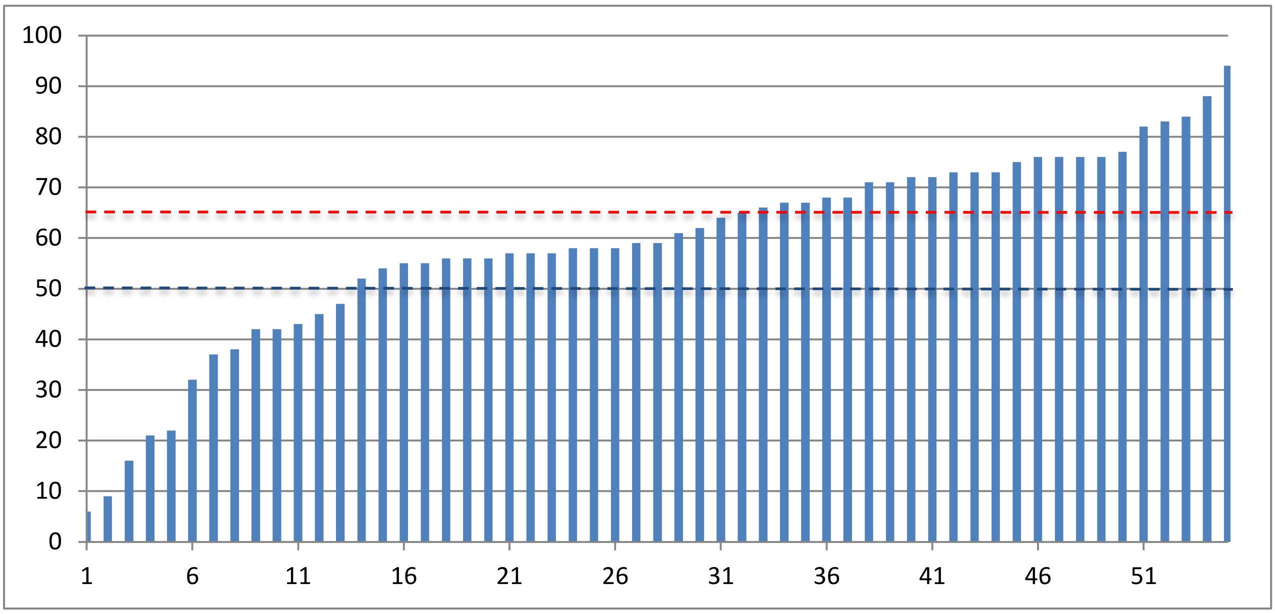

Figure 1: Workplace fatalities showing age of person
Vertical axis: age; Horizontal axis number of fatalities.

Where the initiator of the crash was known, 10 (18.5%) farm work vehicles and 10 (18.2%) recreational vehicles lost control caused by driving over an object, 15 (27.7%) farm work vehicles and 5 (9.1%) recreational lost control on a slope, a further 6 (11.1%) farm work vehicles and 3 (5.5%) recreational vehicles lost control on a slope driving over an object. In other words, 31 (57.4%) farm vehicles and 18 (32.7%) recreational vehicles lost control on a slope and/or driving over an object.

The main cause of death for farm workers was chest injury (59%) compared to head injury for recreational riders (49%). Only 13% of farm workers died as a result of head injury.

A helmet was found to be worn in 24 of the 109 cases. In four of these cases the helmet came off during the crash. In six cases where a helmet had been worn, head injury was the cause of death and in nine cases multi-body injury was the cause of death. The MAIS for the head and cervical spine were lower if a helmet had been worn and stayed on during the crash although difference between the mean MAIS for the head and cervical spine plus spinal cord based on helmet use was insignificant.

Rollover accompanied by being pinned by the Quad bike and asphyxiation was identified as one of the major injury causal mechanisms occurring in farming related crashes. Around 62% of farm workers were pinned under the vehicle without extensive impact related injuries, e.g. received a flail chest. Moreover, fifty-five (50.5%) of the sub-sample 109 deceased riders were pinned by the Quad bike, i.e. the person was pinned under the vehicle until they were released by another person. A higher proportion of farm workers (n=37, 69.8%) were pinned under the Quad bike than recreational riders (n=18, 32.7%). This was the dominant injury mechanism for farm workers and is of particular concern to workplace Work Health and Safety regulators and farmers. Figure 2 shows the roll direction and Quad bike orientation when pinning the rider for the 37 asphyxia cases.

Almost half the farm work fatalities (n=26) were caused by asphyxia or a related condition. In these cases the worker was pinned under the Quad bike and typically suffered no injury to a body region other than the thorax and injuries to the thorax were not otherwise fatal. The data suggest strongly that approximately twenty (20) of the farm workers who died of asphyxia would have survived the crash if the vehicle did not pin them with a force sufficient in terms of magnitude and duration to cause asphyxia. In the other fatal farm work cases a large proportion of those not asphyxiated were injured when the Quad bike interacted with the operator during a rollover.

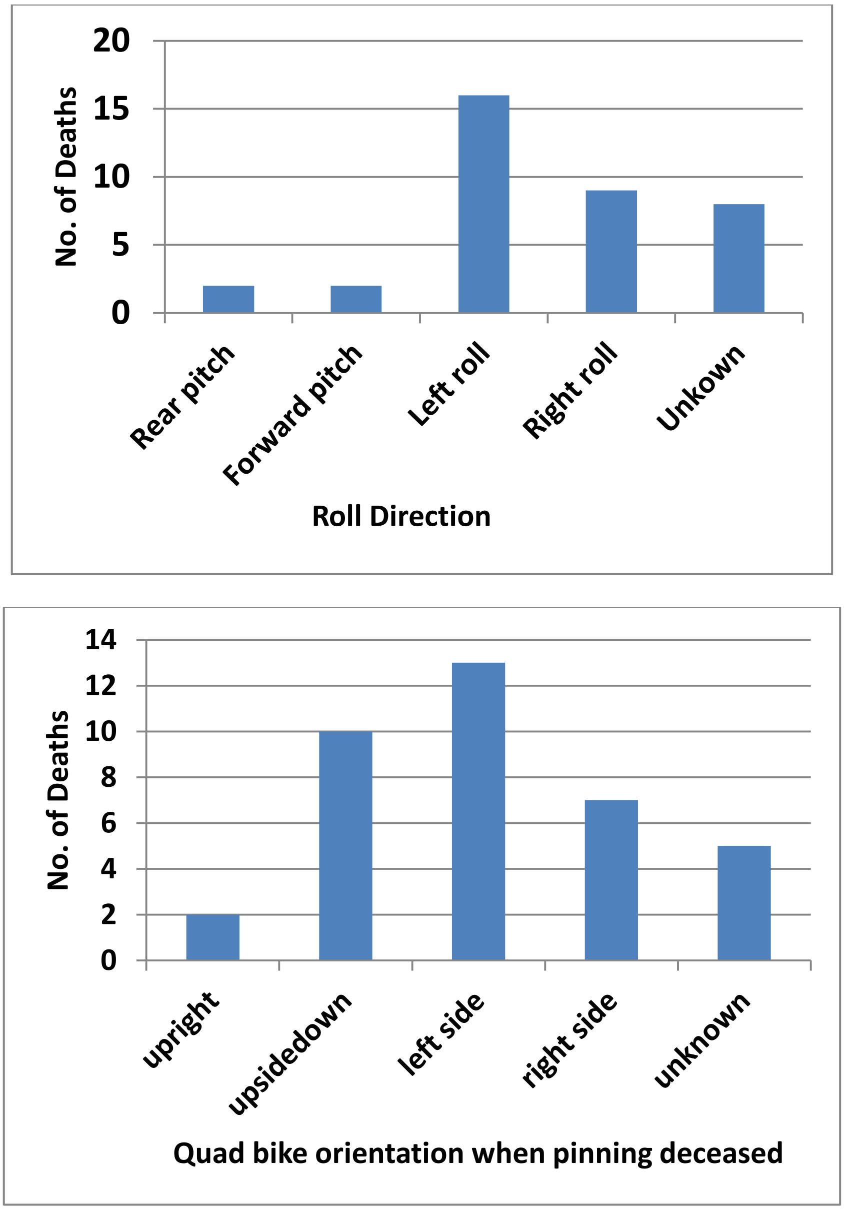

Figure 2: Roll and Orientation characteristics of pinned cases (n=37)

3 Injury Data

In regards to injury data (see Attachment 2), information on the injury patterns and causal circumstances of fatal and non-fatal Quad bike-related injuries was obtained from the following data collections: Safe Work Australia's National Dataset for Compensation-based Statistics (NDS), WorkCover NSW's workers' compensation scheme claims, WorkCover NSW's incident reports, Transport for NSW's Road Crash Analysis System (RCAS), the NSW Admitted Patient Data Collection (APDC), and the NSW Public Health Real-time Emergency Department Surveillance System (PHREDSS).

The data collections examined (Table 1 below) have different inclusion criteria and were examined across different time periods. The NDS (excluding NSW and Tasmania) contained 208 claims related to Quad bike incidents during 1 July 2006 to 30 June 2011. WorkCover NSW's workers' compensation scheme contained 232 claims during 1 September 2003 to 1 July 2011 and WorkCover NSW's incident reports contained 80 incidents during 1 September 2003 to 3 November 2012 for Quad bike incidents. The RCAS identified 12 Quad bike-related fatalities during 1 January 2006 to 16 October 2012. There were 1,515 'special all terrain-related vehicles' identified in the NSW APDC during 1 July 2000 to 30 June 2011 and there were 3,300 Quad bikes, 40 small non-adult Quad bikes, and 11 SSVs identified in the PHREDSS during 1 January 2006 to 31 December 2012.

While information was readily available to describe the demographic characteristics of the injured individual, the information contained within the data collections was not ideal to describe the model of Quad bike (or SSV) and any attachments, the purpose for which the Quad bike/ SSV was being used and the circumstances of the crash, including the geographic typology.

The results from the analysis of the different databases are summarised in the Table 1. For those databases where the characteristics of the Quad bike incident were known, the table shows that rollover is a major casual factor in incidents and that the thorax one of the most common body areas injured.

Finally, it should be noted that the data indicates that over a seven year period there were around 3,307 records of Quad bike/SSV related Emergency Department Presentations (EDP) for NSW (around 472 per year). NSW has a population of around 7.3 million and is around 32% of Australia's total population. Extrapolating the injury count for Quad bikes/SSVs one could expect a total of around 1,400 EDP for Australia each year currently.

Table 1: Summary of all terrain vehicle-related incidents for the six data collections examined

Data collection	Timeframe	Number of quad bike incidents	Most common injuries	Most common body location of injury	quad bike incident	Other comments
SafeWork Australia National Dataset for Compensation-based statistics	1 July 2006 - 30 June 2011 (data provided for different timeframes from each jurisdiction)	n=208 claims, including 2 fatalities	• Sprains & strains (35.6%) • Fractures (29.8%)	• Trunk (29.3%) • Upper limbs (27.4%) • Lower limbs (25.0%)	-	• Workers' compensation claims only • Excludes NSW and Tasmania • Not all injured workers make claims
WorkCover NSW Workers' Compensation Scheme Claims	1 Sept 2003 - 1 July 2011	n=232 claims, including 3 fatalities	• Sprains & strains (41.8%) • Fractures (22.4%)	• Upper limbs (27.2%) • Trunk (24.1%) • Lower limbs (19.4%)	• Fell off quad bike (25.0%) • Quad bike rollover (22.0%)	• Workers' compensation claims only • Not all injured workers make claims • Identification of cases by quad bike classification and text descriptions
WorkCover NSW Incident Data	1 Sept 2003 - 3 Nov 2012	n=80, including 17 fatalities	-	-	• Quad bike rollover (40.0%) • Hit object (23.8%) • Fell off quad bike (13.8%)	• Not all quad bike incidents notified • Identification by searching text descriptions
Road Crash Analysis System	1 Jan 2006 - 16 Oct 2012	N=12 fatalities	-	-	• Quad bike rollover (58.3%)	• Not all quad bike incidents captured.
NSW Admitted Patient Data Collection	1 July 2000 - 30 June 2011	n=1,515, including 4 fatalities	• Fractures (47.6%) • Open wounds (13.3%) • Internal organs (8.7%)	• Head (19.5%) • Knee & lower leg (15.1%) • Thorax (13.2%)	-	• Data quality issues with identification, likely under enumeration
NSW Near Real-time Emergency Department Data Collection	1 Jan 2006 - 31 Dec 2012	n=3,300 quad bikes, n=40 electric quads, and 11 side by side vehicles	• Fractures • Lacerations • Open wounds	-	-	• Possible not all quad bike incidents identified • Identification by searching text descriptions

4 US CPSC Fatalities Compared to Australian Fatalities

Analysis of the United States (US) government Consumer Product Safety Commission (CPSC) database of US Quad bike (ATV) deaths was carried out by McIntosh and Patton and is presented in Attachment 3.

A total of 2718 fatal CPSC cases from the year 2000 were identified and analysed. The selection criteria used is detailed in their report.

Similar to Australia US Quad bike deaths were mainly male (92%) **and t**he median age was 38 years.

A search the free text entry in combination with the ATVD coding of the 2718 cases revealed a total of 1951 crashes involved a rollover (72%). This total is a similar percentage to the Australian data (71%).

In 43% of US cases the Quad bike landed on the rider. This compares to Australian data where 50.5% of the 109 sample investigated in detail were pinned by the Quad bike.

Paved and unpaved roads accounted for the terrain upon which approximately half the incidents occurred where the single most common surface was paved road (30%). This compares to 14 deaths or 10% (out of all 141 cases) involving traffic and public roads for Australian data. It is clear there is an over-representation of deaths occurring on roads in the US whereas Australian deaths occur mostly all off-road.

Forests and farmland accounted for approximately one quarter of the US incidents by terrain compared to three quarters of Australian deaths occurring on farms. However, the activity at time of death, e.g. recreational or farm work, was not documented in the CPSC data set. Nevertheless, it is acknowledged that US fatalities are predominantly resulting from recreational activities.

For the US fatalities, the head was the most common body region injured (53%) followed by the upper trunk (17%). Asphyxia was recorded as occurring in 203 cases (8%). This is in stark contrast to Australian fatalities where 31% died of head injuries, 40% from thorax injuries and 29 of 141 (21%) were attributed to asphyxia (excluding 3 drowning). This is likely the result of US fatalities mainly resulting from recreational activities as opposed to Australian fatalities resulting from a greater proportion of farming activities.

A very strong significant relationship was reported between a rollover event and both asphyxia and anoxia in the CPSC data, and a strong and significant relationship between a rollover event and crush injury. A rollover was associated with a twelve-fold increase in the likelihood of asphyxia compared to no rollover. A rollover was associated with a twofold increase in the likelihood of crush injury compared to no rollover. Rollovers were not associated with blunt force trauma or fractures. As per the Australian fatality cases, there is a trend towards rollover crashes causing crush injuries and, in some cases, asphyxia, and non-rollover crashes resulting in impact related injuries (e.g. head and multi-body).

When the US CPSC ATV fatality data are compared with Australian fatal Quad bike crash data, it would appear that there are similar patterns in terms of crash and resulting injury mechanisms. This is despite the total numbers of rollover versus object impact related fatalities being observably different between the two countries.

The two most important observations are: rollovers mainly cause crush injuries and asphyxia; and non-rollover crashes mainly cause head/neck injuries.

5 Injury Findings of Other Data Bases and Literature Compared to Australian Data

In order to compare the Australian Quad bike fatalities and injuries to other findings from other injury studies, a literature review was carried out using PubMed to identify peer-reviewed articles that investigated fatal and/or non-fatal Quad bike incidents. PubMed is a free database, maintained by the United States National Library of Medicine at the National Institutes of Health, which primarily accesses citations from the MEDLINE database, in addition to other biomedical literature. The keyword search terms were a Boolean combination of “all terrain vehicle”, “all-terrain vehicle”, “atv”, “quad bike”, “quadbike” and “quad-bike”. They found 35 peer-reviewed articles detailing serious and fatal injuries resulting from such incidents. The papers are listed in Attachment 4 in Table 4-1. The countries beside Australia where injury data resulting from Quad bikes was investigated was: US, Canada, Puerto Rico, Ireland, Australia, Germany and New Zealand

The main body regions exposed to serious and fatal injuries from Quad bike incidents were the head and thorax and to a lesser extent the spine and abdomen. The mechanisms of the injuries were typically impact or crush, in addition to a defined group who were asphyxiated in Quad bike crashes. Rollover was reported as a common crash characteristic in the various literature and were reported to account for between 14% to 78% of fatal and injury cases.

The literature confirms that rollover and crush is a major crash and injury mechanism consistent with the current study described in Sections 1.1 and 1.2 in this report.

6 Quad Bike and SSV Crashworthiness Test Protocol

This Section focusses on assessing what likely test protocols could be developed to assess the crashworthiness of Quad bikes and SSVs. McIntosh and Patton analysed and investigated some of the issues concerning rollover crashworthiness in Attachment 5. This section provides a summary of some of that work and discusses some of the relevant issues as the Authors Grzebieta and Rechnitzer perceived them, albeit the final decision for which tests to carry out and how to rate the vehicles was made after receiving the Attachment 5 report. The Final Project Summary Report and the Part 3: Rollover Crashworthiness Test Results present the test methodology and crashworthiness rating methodology that was eventually used.

Having analysed Australian fatality data, US CPSC fatality data, NSW injury data and literature published by other researchers reporting from other countries Quad bike injury and fatality counts and crash and injury mechanisms, it was concluded that for farm workers the typical pattern of severe to fatal injuries is focussed on thoracic injuries, whereas for recreational riders the head is the source of the severe and fatal injuries. There is a small incidence of cervical vertebral and spinal cord injury in both groups. Upper limb and lower limb joint or skeletal injuries are unusual, as are abdominal and pelvic injuries.

It was further concluded that in the case of Australian fatalities related to farming, rollover involving crush injuries to the chest crush and asphyxia from being pinned under the Quad bike were the dominant injury modes. For recreational riders the dominant crash mode was ejection and thus head injuries.

The strong recommendation by all organisations to increase helmet use for all Quad bike operators was reinforced by the analyses discussed in Sections 3 to 5. Not only do Quad bike operators suffer severe head injuries, there is significant evidence to support mandatory helmet use to reduce head injury risk. This recommendation needs to be made most strongly in the context of recreational Quad bike operation. However, it should be reiterated that the development of a Quad bike/SSV helmet that is practical for recreational and farm workers must be considered.

Rollover crashes were strongly associated, and in some statistical analyses significantly associated with chest injury and/or asphyxia. Thus the primary focus for crashworthiness assessment relevant to farm workers in relation to the use of Quad bikes must be thoracic injuries caused by impact forces, crush and/or prolonged static loading on the rider’s chest and air passage ways.

Hence, any tests or safety rating that assist with increasing the rollover resistance of a Quad bike or SSV and thus reduces the likelihood of a rollover, will have a direct effect on reducing rollover associated chest crush and asphyxiation deaths and serious injuries resulting from chest crush. In other words, the results presented in this report clearly justify that vehicles with a higher rollover resistance and dynamic handling that reduce rollover risk, i.e. have a high TTR as presented in PART 1: Static Stability Test Results, and have a favourable understeer characteristic as outlined in PART 2 Dynamic Handling Tests Results, will reduce the number of Quad bike related fatalities and serious injuries.

In regards to assessing the crashworthiness of an SSV, the problem appears straightforward. The SSVs rollover protection structure (ROPS) can be tested for crush strength in a manner similar to the current roof crush test adopted by the Insurance Institute for Highway Safety (IIHS). Thus to obtain a good rating the ROPS would need to have a Strength to Weight (SWR) ratio of around 4 when tested according to the IIHS roof crush test protocol. Variation of the SWR below 4 would be appropriately penalised in terms of point score.

This SSV ROPS crush test could be accompanied by an ejection test, where the SSV is propelled at speed towards a trip bumper, the vehicle is then abruptly stopped and a tip over is initiated to an angle of around 45 degrees where rear tethers limit the tip over. A seat belted Hybrid III Anthropomorphic Test Device (ATD or dummy) placed on the trip side in the SSV (if the SSV has a seat belt) would be observed how well it is contained within the vehicle. Points would be allocated depending on how well the vehicle contains the ATD.

In regards to assessing the crashworthiness of a Quad bike, the issues are more problematic. In regards to crush and asphyxiation, no crashworthiness test have been developed to date that would consider potential for such injuries other than survival space rollover requirements as has already been considered and developed for buses and agricultural and mining machinery. ATDs are optimised for a small set of impact scenarios, e.g. frontal impact, offset frontal impact, side impact, and rear impact. No ATD has been designed specifically to measure crush or asphyxia type injuries. The Hybrid III appears to be the most widely used ATD, possibly because of its availability and ruggedness. However, its fidelity in terms of measuring biomechanical loads and relating them to crush and asphyxia injuries would be totally inadequate if not non-existent.

For example in crush injuries or asphyxia, the Quad bike operator will not undergo a substantial velocity change because a reaction force applied through the ground opposes the force applied by the Quad bike to the operator. This changes the dynamics of the impact process, the biomechanical responses of the body segment and the injury outcomes.

If the operator is on the ground and impacted by the Quad bike, the accelerations of the operator's head and thorax may be low compared to other impact situations. Therefore, measurement of thorax or head acceleration or use of the Head Injury Criterion or Chest Injury Criterion may not necessarily capture the true nature of the chest or head loading. Measurements of forces or deformations are a more valid method for determining the likelihood of injury in this situation without a dummy.

In regards to asphyxia, the Quad bike may remain on top of the operator causing a proportion of the weight force of the Quad bike to be applied to the operator. In these cases the operator is pinned under the Quad bike. Except in a few cases the specific part of the vehicle that pinned the deceased operator was not recorded in the NCIS case series. In some cases a broad area of the Quad bike was on top of the operator. In a few cases specific components were involved, e.g. in one case the foot rest pinned the operator's neck to the ground in a one quarter roll and caused asphyxiation. The operator's posture varies, from prone to supine to side-lying, therefore a unidirectional thorax may not be appropriate for measuring deformation.

In a laboratory based crash test of Quad bike rollovers, an ATD may not be positioned to measure the maximal or relevant loading applied by the Quad bike. Therefore, the building blocks for an alternative test approach were examined by McIntosh and Patton. That test approach was conceptualised by them to not to use an ATD in a laboratory based rollover test, but to measure the impact force applied by the Quad bike to an instrumented floor, the static load and the survival space under the Quad bike.

It was recognised that situations arise in which Quad bike operators are crushed by the Quad bike. Under those situations some of the chest injury criteria presented in Attachment 5 may not be relevant.

The use of an injury criterion of 3.5 kN peak impact force measured during a trip and roll of a Quad onto an instrumented floor was proposed in order to assess thoracic crush injury potential in Quad bike rider rollovers. The force was adopted on the basis of assessing cadaveric test results as outlined in Section 4.2 in Attachment 5.

To assess the potential of asphyxia, a maximum static weight force of 500 N was proposed, equivalent to 50 kg, measured over a period of five minutes. A scaling system could be interpolated with full score at 0 N and no score at 500 N. However, how the test would be carried out in terms of Quad configuration relative to the rider has yet to be considered.

A survival space approach was also considered for inclusion in the crashworthiness assessment in Attachment 5. Sample operator anthropometric dimensions were established. If the objective is to prevent entrapment or pinning of the operator, and the operator has fallen off the Quad bike, then a volume defined by the operator's seated height and the maximum trunk width or depth, would define the space required to guard the operator (head and trunk) if they were to retain a seated posture; i.e. 1030 x 500 x 500 (mm). It was proposed that this can be measured under the Quad bike in a one-quarter roll resting position and up to two two-quarter roll resting positions for which there is vertical clearance of 500 mm is measured. Without a crush protection device or ROPS structure, all Quad bikes would fail this requirement and thus the test may be impractical. Quad operators may also be ejected and not in an upright seated posture when the Quad bike interacts with them.

There is a great deal of variation in the possible postures of the operator and position relative to the Quad bike. In the Australian cases reviewed in depth, there were a number of cases in which the operator remained in the Quad bike's seat, albeit in an inverted position. The majority of fatally injured operators were not in a seated posture or position when found.

Crashworthiness Test Methodology Used

After carrying out a number of preliminary tests at the Roads and Maritime (RMS) Crashlab facility in Huntingwood in the outskirts of Western Sydney, the lead Authors Grzebieta and Rechnitzer settled on the following findings.

1. As a result of the rollover testing, it became apparent that it is currently unrealistic to discriminate the rollover crashworthiness between different Quad bike models. However, discrimination between vehicle types (i.e., Quad bikes and SSVs) was feasible;
2. It was concluded that the term "Crashworthy Quad bike" is fundamentally a contradiction in terms. Therefore, all Quad bikes were rated equally for rollover crashworthiness and assigned the same points baseline rating for rollover crashworthiness protection;
3. It is not possible at present to discriminate Quad bike crashworthiness performance based on real world crash information (in contrast to passenger vehicles, for example), due to the absence of make/model/year (MMY) crash involvement injury data and exposure data collected for Quad bikes and SSVs. This fundamental deficiency with data collection for Quad bikes (and SSVs) remains an impediment to advancing Quad bike safety;
4. The fitment of Operator Protection Devices (OPDs) to Quad bikes is seen by safety stakeholders as an engineering control that may reduce injury risk in some circumstances. However, the industry claim via their own analyses is that OPDs might increase injury risk in some circumstances, although their hypothesis is not supported by any reported Australian cases from real world crash data. As with motorcycles, the safety crashworthiness basis promoted by industry for Quad bikes is separation. Similarly if increased crash protection is a key performance requirement then different vehicle types, e.g. SSVs, which offer such protection as part of their design need to be considered and used instead, in line with choosing 'Fit For Purpose' vehicles within the risk management framework;
5. In contrast to Quad bikes, the SSVs do adhere in general to rollover crashworthiness principles, in that they are fitted with ROPS, seatbelts and various degrees of occupant containment measures which combine to keep the occupants within the protected space. The effectiveness of such designs in terms of severe injury prevention can vary widely. It is possible to discriminate and to rate SSV crashworthiness;

6. A well designed SSV with a ROPS and appropriate seatbelt restraint (3 point or harness) can provide good protection in rollover crashes that typify farm rollover incidents as identified in Coronial data. For this reason the vehicle type (SSV or Quad bike) should not be distinguished as such when assessing rollover crashworthiness protection (similar to assessing the vehicles for static stability and the dynamic handling). The focus of the rating system is to identify for the workplace/farming consumer which vehicle offers the best protection in a rollover crash regardless of vehicle type protection system (ROPS with Seat belts or only an OPD), except that some systems offer more protection than others, with points rated accordingly.

Considering the above context, it was decided that the rollover crashworthiness test methodology and rating system should consist of following:

1. Measurements of static ground contact force with and without an Operator Protection Device (OPD) on its left and right side and when inverted. The mass difference between different model Quad bikes was not sufficient to provide significant discrimination in terms of asphyxia potential, as in most cases the 50 kg asphyxia load criterion would be exceeded;
2. Inspection and measurements of Side by Side Vehicle (SSV) occupant retention in accordance with the United States (US) American National Standard for Recreational Off-Highway Vehicles ANSI/ROHVA 1-2011 with additional requirements applied, as discussed in Section 2.5.2;
3. Vehicle and rider/driver dynamic rollover tests consisting of positioning a ATD in the operator's position of a Quad bike or Side by Side Vehicle, tilting the vehicle to an angle at which rollover would occur, and releasing the vehicle from an initial static position to rollover to observe 'survival space'[2] and functionality of the OPD, and in the case of the two SSVs the ROPS and restraints.
4. Side by Side Vehicle (SSV) ROPS structure load tests consisting of applying a lateral load followed by a vertical load then a longitudinal load to the vehicle ROPS whilst recording the deflection and noting the structural integrity, in accordance with the ISO (2008) test option for the US ANSI/ROHVA 1-2011 requirements. (Note that there are two test methods for compliance: the ISO 3471:2008(E) (ISO, 2008) method and the OSHA method (Code of Federal Regulations). In this study, the ISO 3471:2008(E) test method was used).

Part 3: Rollover Crashworthiness Test Results provides further details regarding the test procedures and results.

[2] 'Survival space' is intended to mean here the space left between the upturned Quad bike and the ground from which a rider can crawl

7 References:

1. Code of Federal Regulations, Title 49, Part 565, Vehicle Identification Number Requirements: Part 571, Federal Motor Vehicle Safety Standards (FMVSS) and Part 574, Tire Identification and Record Keeping: Code of Federal Regulations. 29 CFR 1928.53 OSHA (performance requirements for a protective enclosure designed for wheel-type agricultural tractors)

2. International Standard (ISO), ISO 3471:2008(E), Fourth edition 2008-08-15, Earth-moving machinery - Roll Over protective structures - Laboratory tests and performance requirements.

3. Rechnitzer, G., Grzebieta R.H., McIntosh A.S., and Simmons K. (2013). “Reducing All Terrain Vehicle Injuries (ATVs) And Deaths - A Way Ahead”, Proc. 23rd International Safety Conference on the Enhanced Safety of Vehicles, Soeul, Korea, May, Paper No. 13-0213.

4. Recreational Off-Highway Vehicle Association, (2011). American National Standard for Recreational Off-Highway Vehicles, ANSI/ROHVA 1 - 2011, Recreational Off-Highway Vehicle Association, California, USA.

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[3] This includes both manufacturers and distributors of Quad bikes and Side by Side Vehicles (SSVs). For convenience in this report, where we note the Quad bike industry this includes manufacturers and distributors of both Quad bikes and SSVs.

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Disclaimer

<ins>The analyses, conclusions and/or opinions presented in this report are those of the Authors</ins> and are based on information noted and made available to the Authors at the time of its writing. Further review and analyses may be required should additional information become available, which may affect the analyses, conclusions and/or opinions expressed in this report.

While the project has been widely researched and developed, with much input from many sources worldwide, the research methods, ratings system, conclusions and recommendations are the responsibility of the Authors. Any views expressed are not necessarily those of the funding agencies, the Project Reference Group (Appendix A), FCAI or others who have assisted with this Project.

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ATTACHMENT 1: Quad Bike Fatalities In Australia: Examination Of Crash Circumstances And Injury Patterns by Dr. Andrew McIntosh and Dr. Declan Patton.

REPORT 2013

QUAD BIKE FATALITIES IN AUSTRALIA: EXAMINATION OF CRASH CIRCUMSTANCES AND INJURY PATTERNS

By:

Dr Andrew S McIntosh

Dr Declan Patton

Date: 12 December 2013

Executive Summary

This study was commissioned as part of the Quad Bike Performance Project, to provide the detailed circumstances and fatal injuries related to Quad bike and Side by Side Vehicle usage in Australia, obtainable from the detailed Coronial case files.

A search of the National Coronial Information System (NCIS) dataset of fatalities in Australia between 2000 and 2012 identified 141 closed cases involving all-terrain vehicles. All available case documents in the NCIS dataset were reviewed and it was determined that the full coronial files were required. These were obtained from the coroner(s) in each state. After review of the 141 cases, 32 were excluded from further analysis. Those excluded included crashes on roads with other vehicles, and vehicles that were not grouped within the terms of reference of the project, e.g. dune buggies. An extensive case series review and analysis of 109 fatal all-terrain vehicle[1] crashes in Australia was undertaken; these are referred to as the 'included' cases and are a sub sample of the 141 cases. The objectives were to describe the characteristics of fatal incidents, describe the pattern of injuries, including fatal injuries, and consider the injury mechanisms.

Data were extracted from each set of case documents and coded according to a set of fields under seven general topics: General, Temporal, Demographic, Vehicle, Environment, Crash and Injury. In total 99 fields were coded. In the majority of cases each field could be coded based on the available information to a suitable level. When the information was not available or unclear, the field was labelled as "unknown".

NSW and Queensland were the states in which approximately half the 141 and 109 included fatal Quad bike and SSV incidents and crashes occurred. The deceased person was male in 86% of the included 109 cases with an age range from four years to 94 years. The mean height and body mass for all included cases in the age group 15 to 74 years were 1.75 m and 81 kg, respectively. This compares well to normative data for adult males.

Fifty three (53) of 54 work related fatalities occurred during a farming activity. The other single workplace case was an emergency services related case. Fifty five (55) cases were associated with recreational activity.[2] The farm was also the location of many fatal recreational incidents and in total was the location for approximately three quarters of all the 109 incidents. State forests and beaches were the next most frequent locations for recreational incidents. The terrain and surfaces were consistent with the general locations.

Summer was the period with the highest proportion of fatal incidents. The time of day of the incidents was distributed across the full 24 hour period, but the most common period for farm work incidents was Monday to Friday between 9 am and 3 pm (34%). Farm work related fatal

[1] In this report 'all-terrain vehicle' includes all Quad bikes, a six wheel bike, and Side by Side Vehicles.

[2] **Definitions of work and recreational cases.** These are based on reviewing the Coronial case files and determining the activity being undertaken by the vehicle rider/ driver at the time of the fatal incident. That is whether the activity was work related in some way or recreational related. In regard to work related activities the relevant activities are listed in Appendix B. Recreational is defined as per the Oxford Dictionary "Relating to or denoting activity done for enjoyment when one is not working".

incidents are often occurring during what might be considered normal working hours for the general population and not at unusual time of the day or week.

There were 106 Quad bikes, two SSVs and one six wheel off-road vehicle[3] in the sample of 109 cases. Yamaha, Honda and Suzuki were the suppliers of approximately 65% of the vehicles. The majority of the vehicles were common brands. Between approximately 45% and 60% of farm workers had some form of attachment on the vehicle. The upper limit of 60% is provided because the use of an attachment was unknown in 26% of the farm work cases. Few recreational operators had an attachment. Only one Quad bike had an operator protection device (OPD) and that was not relevant to the incident and the outcome of the crash as it did not involve a rollover and was a frontal collision.

What was termed “loss of control” was considered the initiator of the majority of the crashes. For farm workers loss of control occurred on slopes or was caused by striking an object, e.g. a rut or a branch. There was a broad range of factors that contributed to the initiation of the crash. In contrast to loss of control, in some cases the vehicle collided with an object and in others the operator collided with an object, e.g. pipe or boom gate.

The vehicle rolled in the majority of cases and this was more likely to occur on a slope and with the use of attachments than on the flat with no attachments. However, the available data provides insufficient detail to determine if the use of attachments was causal or rather one of the contributing factors to rollovers. The speed of the vehicles was largely not quantified, but the impression gained from reading the case files is that farm workers were driving at slow speeds when they rolled, whereas recreational operators were driving at high speeds when they rolled. The ratio of lateral to rearward to forward rolls (with a known roll direction) was 6.4 to 1 to 2.2.

The analyses show that the main causes of death and serious injury are head and thoracic injury, including mechanical or traumatic asphyxia. There is also a clear, but relatively small, incidence of fatal and serious cervical spine injury. It is also noted that in asphyxia cases related to farms there appeared to be an over representation of cases in which it is known the Quad bike had an attachment (13 out of 22, i.e. 60%) and compared with 13 out of 37 (35%) pinned and 16 out of 54 (30%) of all workplace cases.

There was a clear difference in the body region and type of injuries that caused the deaths of farm workers and recreational riders. The main cause of death for farm workers was chest injury (59%) compared to head injury for recreational riders (49%). Only 13% of farm workers died as a result of head injury. There was a higher proportion of multibody cause of death for recreational riders compared to farm workers, 20% to 7%, respectively.

The causes of death are consistent with the crash characteristics. In the case of farm workers this typically involved being pinned by the vehicle as a result of a rollover, whereas the recreational rider was typically ejected from the vehicle hit an object in the environment at high speed and/or interacted with the moving Quad bike. For example, in some cases the rider was ejected at speed, hit a tree and then was crushed by the Quad bike.

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[3] This is effectively a ‘Quad bike’ however with six wheels and not four. It is ridden similar to a Quad bike using handle bars for steering and a straddle rider position.

Crush and a combination of crush and impact were considered the mechanism of the majority of the fatal farm work injuries. In contrast an impact was considered the mechanism of the majority of recreational fatal injuries.

Almost half the farm work fatalities (n=26) were caused by asphyxia or a related condition. In these cases the worker was pinned under the Quad bike and typically suffered no injury to a body region other than the thorax and injuries to the thorax were not otherwise fatal. The data suggest strongly that approximately twenty of the farm workers who died of asphyxia would have survived the crash if the vehicle did not pin them with a force sufficient in terms of magnitude and duration to cause asphyxia. In some asphyxia cases, accessories and/or cargo were present on the vehicles. In the other fatal farm work cases a large proportion of those not asphyxiated were injured when the Quad bike interacted with the operator during a rollover.

The interaction of the weight and/or energy of the vehicle with the operator during a low speed crash with a rollover is the most important cause of fatal farm work injury. In contrast, the interaction of the recreational rider's energy with unyielding elements in the natural and built environments is the primary cause of fatal recreational rider injury, coupled with the interaction of the energy of the Quad bike with the rider after the rider has been ejected.

There are a number of contributing factors. The isolated nature of farm work in terms of remoteness and working alone is likely to be a contributing factor in Quad bike deaths. Intoxication was not coded in this analysis. Other 'warned-against behaviours'[4] (on mandatory warning labels) were often present, such as not wearing a helmet, children[5] riding adult sized ATVs, passengers on Type 1 (single seated) ATVs, operation on paved surfaces and on public roads, excessive load, excessive speed, etc. In general, the case reports showed that there was a level of intoxication associated with recreational crashes. In some cases, multiple contributing factors were present in recreational crashes, e.g. speed, fatigue, low light, intoxication and unfamiliar terrain. Those factors were normally not associated with farm work crashes.

Twenty four operators wore a helmet at the time of the crash. In four cases the helmet was ejected. A trend was apparent that a helmet offered some protection to the head, although on an individual case basis some riders suffered massive head injuries even when wearing a helmet. It was not determined in the current study whether helmets worn met the applicable Australian standard, or whether they were properly fastened at the time of the incident.

One of the initial reasons for the case series review was to inform the development of crashworthiness assessments of Quad bikes. In short, the analyses indicate that reducing the propensity for the vehicle to roll, improving the handling so that loss of control events are reduced, particularly when there is a perturbation, and managing the interaction between the vehicle and the operator in a rollover are three important areas.

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[4] The industry uses the term 'warned against behaviour' as representing actions taken by a rider on Quad bikes which are warned against on the safety warning labels fitted to the vehicles. The Authors note that from a safety perspective simply warning riders using such labels is a low level administrative control and which is known to be of low effectiveness in the hierarchy of controls.

[5] The use of the term 'children' or 'child' or 'youth' is defined by an age of 15 years or younger.

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1 Introduction

This study was commissioned as part of the Quad Bike Performance Project, to provide the detailed circumstances and fatal injuries related to Quad bike and Side by Side Vehicle usage in Australia, obtainable from the detailed Coronial case files.

The Register of Quad Bike Deaths from the National Farm Injury Data Centre (NFIDC), which is maintained by the Australian Centre for Agricultural Health and Safety (AgHealth), is sourced from the Australian National Coronial Information System (NCIS). The NCIS is a data storage, retrieval, analysis, interpretation and dissemination system for coronial information, which is an initiative of the Australasian Coroners Society and managed by the Victorian Department of Justice on behalf of a Board of Management. It contains data about deaths reported to Australian coroners from July 2000, for all states and territories with the exception of Queensland data, which is reported from January 2001. NFIDC adds new cases to the Register of Quad Bike Deaths by two methods: firstly, periodic searches of the NCIS database; secondly, daily Media Monitors programme alerts. Media Monitors is a privately owned company, which is contacted by the NFIDC to keyword search approximately 2500 publications Australia-wide and provide auto-generated daily reports. Any reported Quad bike death is added to the Register of Quad Bike Deaths and the NCIS is notified.

As of 2012, the Register of Quad Bike Deaths contains over 160 fatally cases. Lower *et al.* (2012, 2013) analysed 127 of the cases, which occurred between 2001 and 2010. Approximately 45% were considered work-related, which occurred predominantly in the farm setting and were due to rollover. A limitation identified by Lower *et al.* (2013) was the variable depth of information available through the NCIS for each of the cases and it was suggested that further studies include detailed analysis of the incidents. For each case, the NCIS may include the police report narrative, autopsy report, toxicology report and the coroner's findings; however, not all documents are available for all cases and the level of detail in each document varies between cases, e.g. the police reports range from single sentence summary to a full page detailed description.

The aim of this report was to obtain the full briefs of evidence for all the Quad bike fatality cases recorded by the NCIS and to:

a) describe fatal Quad bike incidents;

b) describe the pattern of injuries among fatally injured Quad bike operators; and

c) consider the mechanisms of injury as they relate to the interactions between the operator, the vehicle and the environment.

2 Methods

2.1 Ethics Approval

The study received the following ethics approval:

- University of New South Wales (UNSW) Human Research Ethics Advisory (HREA) Panel 'H' Science & Engineering, reference number 08/2012/62.
- Victorian Department of Justice Human Research Ethics Committee (JHREC), reference number CF/12/22763.
- National Coronial Information System (NCIS), project number M0267.
- Western Australia Coronial Ethics Committee (WACEC), reference number EC03/13.

2.2 Search Strategy

The NCIS system was initially searched for closed fatal Quad bike cases, during the period 2000 to 2012, using a Boolean combination of the following search terms: “Quad bike”, “Quadbike”, “Quad-bike”, “ATV”, “all terrain”, “all-terrain”, “off road”, “off-road” and “vehicle”. In addition, a second search was conducted using the object section of the NCIS query design to select: category 1, “mobile machinery or special purpose vehicle”; category 2, “other mobile machinery or special purpose vehicle”; description, “special all-terrain vehicle/off-road vehicle, Quad bike”. The case lists returned from the two search strategies were collated and compared to the Register of Quad Bike Deaths from the NFIDC.

2.3 Data Extraction Protocol

All files available on the NCIS were retrieved and stored securely, in accordance with NCIS and UNSW policies. After a review of the available files it was determined that the full brief of evidence containing the primary documents for each case was required; therefore, written requests were submitted to the coroners’ courts in all states and territories. However, the state courts had different protocols in terms of document access, which ranged from providing copies of the full evidence briefs to allowing researchers to visit the courts, view the files and take notes.

2.4 Case Review and Coding Protocol

An initial review of every case was undertaken and a preliminary decision was taken regarding the inclusion of each case in the main analysis. Cases were immediately excluded if they involved an on road or similar collision with a motor vehicle, e.g. car, truck or train, or if they did not involve a Quad bike. All cases were reviewed with a focus on the characteristics related to the individual, temporal factors, vehicle, environment, crash and injuries. A focus was to ascertain the relationships between crash characteristics, e.g. rollover and injury. Cases were coded (Table 1-1). Specific cases were presented and discussed with others in the investigation team authorised to review and discuss these cases.

Table 1-1: Coded fields.

Topic	Fields	Comments
General	State	
Temporal	Month, Season, Day of week, Time of incident, Time of death, Interval between incident and death	Time of day during the week were analysed according to method developed by McClean *et al.*[3] (Figure 1-1)
Demographics	Gender, Age, Stature and Body Mass, Recreation or work, Specific activity at time of incident, Industry (work related), Helmet	Stature and body mass were not always measured or reported
Vehicle	Type (Quad bike, side-by-side, other), Make, Model, Engine Capacity, Build Year, Attachments at time of incident, Operator protection device	
Environment	Terrain, Ground cover, Slope, Collision partner	
Crash	Initiator, Rollover, Speed, Roll characteristics, Free text	
Injury	Cause of death (region, nature and main mechanism), Pinning of operator, Injuries by body region and anatomical part, MAIS coding of cranium, cervical spine, thorax and abdomen, Asphyxia, Mechanisms of main injuries, Free text	AIS 2005[4] used for coding MAIS

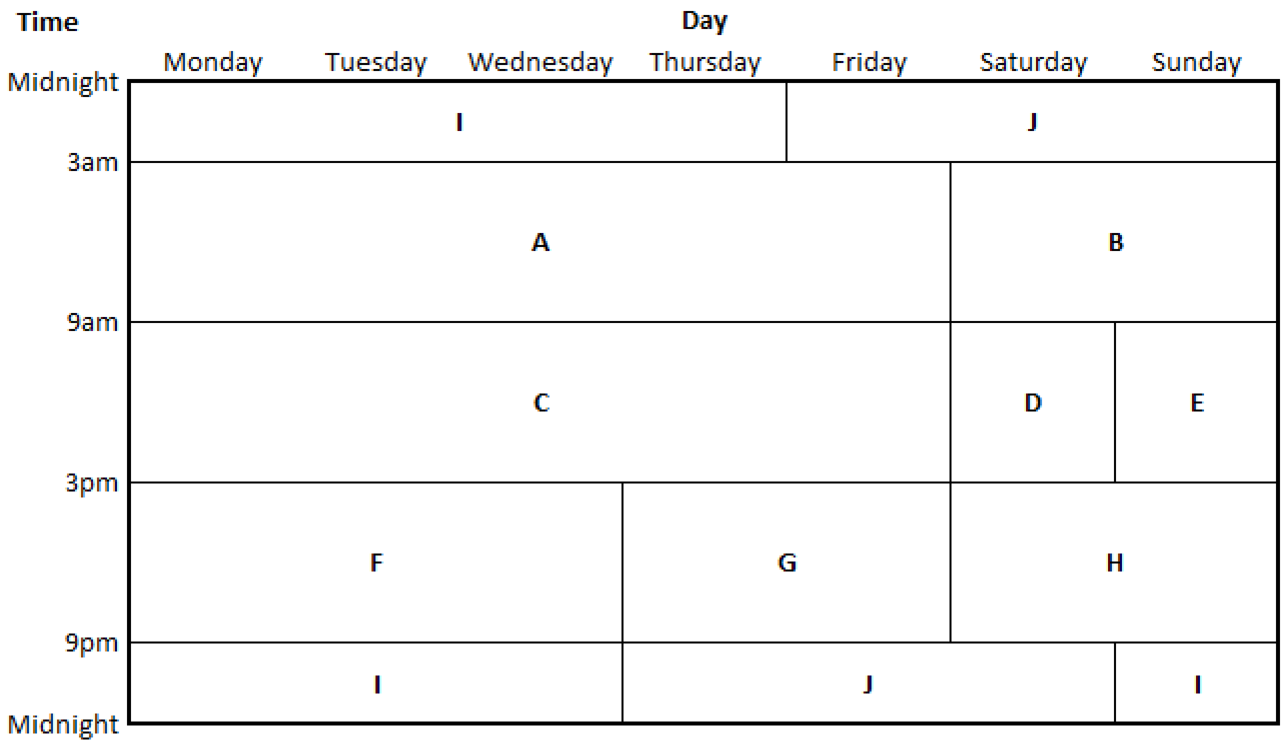

Figure 1-1: Week split into ten time periods, "A" to "J", as per McClean *et al.* (1980)

The severity of the most severe injury for each of the body regions cranium, cervical spine and cervical spinal cord, thorax and abdomen were coded according to the Abbreviated Injury Scale (AIS) 2005 (Gennarelli and Wodzin, 2005). The Maximum AIS severity (MAIS) is a number from 0 to 6 or 9. Zero (0) is no injury, 1 is minor, 2 is Moderate, 3 is Serious, 4 is Severe, 5 is Critical and 6 is Maximal. Nine (9) is applied when the specific details of a typically critical to maximal injury are unknown.

2.6 Data Aggregation and Analysis

Field entries were reduced to standard descriptor codes for statistical analyses. All statistical analyses were undertaken in IBM SPSS version 21. Descriptive analyses were performed. Associations between incident factors and injury outcomes were also assessed. This report presents largely descriptive analyses.

3 Results

3.1 All Cases

A total of 141 closed fatal cases were identified to have involved a Quad bike and reported to Australian coroners between 2000 and 2013.

3.1.1 State

The majority of the Quad bike fatalities occurred in NSW and Queensland, which accounted for almost half of the total cases Australia-wide (Table 1-2).

Table 1-2: Distribution of cases by state.

State	Excluded		Included*		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
ACT	1	3.1%	0	0.0%	1	0.7%
NSW	9	28.1%	25	22.9%	34	24.1%
NT	1	3.1%	6	5.5%	7	5.0%
QLD	5	15.6%	29	26.6%	34	24.1%
SA	4	12.5%	4	3.7%	8	5.7%
TAS	2	6.3%	11	10.1%	13	9.2%
VIC	7	21.9%	14	12.8%	21	14.9%
WA	3	9.4%	20	18.3%	23	16.3%
Total	**32**	**100.0%**	**109**	**100.0%**	**141**	**100.0%**

*Included represent the cases in the main analysis.

3.1.2 Gender

In the included cases, 95 of the 109 (87.2%) were male (Table 1-3).

Table 1-3: Distribution of cases by gender.

Gender	Excluded		Included		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Female	11	34.4%	14	12.8%	25	17.7%
Male	21	65.6%	95	87.2%	116	82.3%
Total	**32**	**100.0%**	**109**	**100.0%**	**141**	**100.0%**

3.1.3 Age

Fatally injured Quad bike operators and passengers were distributed from the very young to the very old (Table 1-4). The median and mean ages of victims fatally injured in Quad bike incidents were 38 and 40 years, respectively. The age group with the highest proportion of fatal cases was 15 to 24 years (Table 1-5).

Table 1-4: Statistics for the age distribution of Quad bike victims.

Statistics	Age [years]		
	Excluded	Included	Total
Mean	33	43	41
Standard Deviation	25	24	25
Median	21	43	38
Minimum	1	4	1
Maximum	87	94	94

Table 1-5: Statistics for the age distribution of Quad bike victims.

Age group [years]	Excluded		Included		Total	
	Number	Percentage	Number	Number	Percentage	Number
0-4	3	9.4%	5	4.6%	8	5.7%
5-15	7	21.9%	11	10.1%	18	12.8%
16-24	7	21.9%	17	15.6%	24	17.0%
25-34	2	6.3%	11	10.1%	13	9.2%
35-44	4	12.5%	13	11.9%	17	12.1%
45-54	0	0.0%	9	8.3%	9	6.4%
55-64	3	9.4%	17	15.6%	20	14.2%
65-74	4	12.5%	14	12.8%	18	12.8%
75-84	1	3.1%	10	9.2%	11	7.8%
85-94	1	3.1%	2	1.8%	3	2.1%
Total	**32**	**100.0%**	**109**	**100.0%**	**141**	**100.0%**

3.1.4 Anthropometric Data

Stature and body mass data were available in a proportion of the cases. In some cases, only body mass was available or only stature. A total of 73 of the included cases reported both body mass and stature; in addition, stature or body mass only were reported in 14 and 2 cases, respectively. Few of the excluded cases had anthropometric data. The median person from all cases was 1.74 m tall and had a body mass of 74 kg (Table 1-6). The data include a broad age group.

Table 1-6: Anthropometric characteristics of Quad bike victims.

Statistics	Stature [m]			Body mass [kg]		
	Excluded	Included	Total	Excluded	Included	Total
Mean	1.74	1.69	1.69	76	74	74
Standard Deviation	0.18	0.19	0.19	5	23	23
Median	1.74	1.74	1.74	76	74	74
Minimum	1.61	1.01	1.01	72	18	18
Maximum	1.86	1.94	1.94	79	133	133

3.1.5 Vehicles

In total there were 133 Quad bikes, 6 side-by-side vehicles, one six-wheeled Quad bike and one five-wheeled lawn tractor.

3.2 Excluded Cases

After review of the 141 cases, 32 were excluded for specific reasons (Table 1-7). Most cases were excluded for being traffic incidents and/or the passenger was the victim, which was often in an unusual manner.

Table 1-7: Reasons for excluding cases.

Reason	Excluded	
	Number	Percentage
Traffic	9	28.1%
Traffic/passenger	5	15.6%
Passenger	2	6.3%
Preexisting cause of death	2	6.3%
Not operating	2	6.3%
Other	12	41.2%
Total	**32**	**100%**

3.3 Included Cases (A) – Incident and Crash Characteristics

3.3.1 Demographics

The total number of cases in the full analysis was 109. The rest of the report describes incident, crash and injury characteristics for those 109 cases. When only the included cases are considered (Table 1-8), NSW and Queensland still accounted for almost 50% of the cases and 15-24 year olds accounted for 16.5% (n=18) of the included cases. Eighty seven percent (n=95) were male. The median person from all included cases was 43 years old, 1.74 m tall and weighed 74 kg. The mean height and body mass were 1.69 m and 74 kg, respectively. This compares to the mean height and body mass for the adult male USA population of 1.77 m and 83 kg, respectively.

These descriptive statistics include children as well as adults. The mean age for those killed during a work activity in the 15 to 74 years age group was 56 years compared to 31 years for recreational operators in the same age range (Table 1-9). The mean height and body mass for the work-related fatalities (n=54) in the age group 15 to 74 years were 1.74 m and 85 kg (Table 1-10). The mean height and body mass for those killed in recreational related incidents (n=55) in the age group 15 to 74 years were 1.76 m and 78 kg. The mean height and body mass for all included cases in the age group 15 to 74 years were 1.75 m and 81 kg. This compares to the mean height and body mass for the adult male USA population of 1.77 m and 83 kg, respectively (International Organisation for Standardisation, 2010). Comparative data are not available for Australia, and children are included in the 109 cases. All 24 cases in which a helmet was worn were included in the sample of 109 cases.

Table 1-8: Age group distribution of victims.

Age group [years]	Activity at time of crash			
	Work (53 farm and 1 other)		Recreational	
	Number	Percentage	Number	Percentage
0-4	0	0.0%	5	9.1%
5-15	2	3.7%	9	16.3%
16-24	3	5.6%	14	25.4%
25-34	1	1.9%	10	18.2%
35-44	4	7.4%	9	16.4%
45-54	4	7.4%	5	9.1%
55-64	16	29.6%	1	1.8%
65-74	13	24.1%	1	1.8%
75-84	9	16.7%	1	1.8%
85-94	2	3.7%	0	0.0%
Total	**54**	**100.0%**	**55**	**100.0%**

Table 1-9: Statistics for the age distribution of victims.

Age group [years]	Activity at time of crash			
	Work (53 farm and 1 other)		Recreational	
	Number	Percentage	Number	Percentage
Children (0-15 years)	2	3.7%	14	25.5%
Adults (16-74 years)	41	75.9%	40	72.7%
Adults (>75 years)	11	20.4%	1	1.8%
Total	**54**	**100.0%**	**55**	**100.0%**

Table 1-10: Anthropometric characteristics by age group and activity.

Age group [years]	Anthropometric characteristics	Activity at time of crash									
		Work (53 farm and 1 other)					Recreational (n=55)*				
		Mean	S.D.	Median	Min.	Max.	Mean	S.D.	Median	Min.	Max.
Children (0-15 years)	Height (m)	1.26	0.13	1.26	1.17	1.35	1.38	0.31	1.39	1.01	1.84
	Mass (kg)	33	7	33	28	38	45	21	55	18	82
Adults (16-74 years)	Height (m)	1.74	0.10	1.76	1.51	1.94	1.76	0.06	1.76	1.64	1.90
	Mass (kg)	85	20	81	54	133	79	15	78	54	122
Adults (>75 years)	Height (m)	1.74	0.05	1.74	1.65	1.81	1.63	0.0	1.63	1.63	1.63
	Mass (kg)	75	10	77	65	92	67	0.0	67	67	67
All	Height (m)	1.72	0.14	1.75	1.17	1.94	1.66	0.23	1.74	1.01	1.90
	Mass (kg)	80	22	77	28	133	69	23	72	18	122

3.3.2 Industry and Location

The included cases were almost evenly divided by the general activity being undertaken at the time of the incident; 53 farm work, one other work and 55 recreational. The main farming industry was livestock-related agriculture (Table 1-11). List of farm work activities at time of crash are given in Appendix B.

Table 1-11: Industry in which the fatality occurred.

Age group [years]	Included	
	Number	**Percentage**
Agriculture - alpaca	1	0.9%
Agriculture - dairy	22	20.2%
Agriculture - grain	1	0.9%
Agriculture - contractor*	3	2.8%
Agriculture - unknown	1	0.9%
Agriculture – horse/cattle	1	0.9%
Agriculture - unknown	24	22.0%
Health and community services	1	0.9%
Recreational	55	50.5%
Total	**109**	**100.0%**

*Vegetation controller.

Farm related incidents occurred on farms during farming work, e.g. mustering, spraying, transport and maintenance; whereas, recreational incidents occurred in a range of locations (Table 1-12). The three main locations for recreational incidents were farms, beaches and state forests. Therefore, the farm is the location for almost three quarters (73.4%) of the 109 ATV related deaths in this analysis, regardless of activity at the time. State forests (9.2%) and beaches (7.3%) are the second and third most frequent incident locations, respectively. A number of on-road incidents involving ATV to motor vehicle crashes were excluded from set of 109 cases.

Table 1-12: Areas where fatalities occurred.

General location	Activity at time of crash			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
Beach	0	0.0%	8	14.5%
Driveway	0	0.0%	1	1.8%
Farmland	53	100.0%	27	49.1%
Motocross park	0	0.0%	1	1.8%
Public land	0	0.0%	1	1.8%
Public road	0	0.0%	3	5.5%
Quarry	0	0.0%	1	1.8%
Racetrack	0	0.0%	1	1.8%
Railway easement	0	0.0%	1	1.8%
Road	0	0.0%	1	1.8%
State forest	0	0.0%	10	18.2%
Total	**53***	**100.0%**	**55**	**100.0%**

*Additional (other) workplace incident occurred on a public road

3.3.3 Temporal Factors

The month, day of week and time of day were analysed. For all cases, the months with the most and least number of cases were January (n=16, 14.7%) and September (n=3, 2.8%), respectively (Table 1-13). In terms of season, summer, which was defined as December to February, had the greatest proportion with almost one third of all cases. Almost one quarter of all cases occurred on a Monday to Friday during the middle of the day, 9am to 3pm. In some cases, the time of the incident was provided as a very broad interval and was coded as "unknown". For example, the time a person was last seen was known, but then they were not found for twelve or more hours and there were no witnesses.

Table 1-13: Seasonal and monthly distribution of cases.

Season of incident	Month of incident	Activity at time of crash			
		Farm work		Recreation	
		Number	Percentage	Number	Percentage
Summer	January	4	7.5%	12	21.8%
	February	6	11.3%	4	7.3%
Autumn	March	8	15.1%	4	7.3%
	April	5	9.4%	6	10.9%
	May	5	9.4%	6	10.9%
Winter	June	3	5.7%	7	12.7%
	July	3	5.7%	2	3.6%
	August	3	5.7%	4	7.3%
Spring	September	2	0.0%	1	1.8%
	October	5	9.4%	1	1.8%
	November	5	9.4%	4	7.3%
Summer	December	4	7.5%	4	7.3%
Total		**53***	**100.0%**	**55**	**100.0%**

*Additional (other) workplace incident occurred in February

When the included cases are analysed by activity at time of crash, approximately a third of the farm work incidents occurred during the working hours of 9am to 3pm, on a weekday (Table 1-14, Figure 1-2). In some cases, e.g. eight work cases, the time of the incident was not known to within the boundaries of the coding system. For example, a person was known to have been last seen at a specific time, but they were not seen again for twelve or more hours at which time they were found deceased. In comparison to work cases, more recreational cases occurred on the weekends and late at night (Figure 1-3).

Table 1-14: Day of the week and timing of incidents.

Time/Day of incident**	Activity at time of crash			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
A (3am-9am) Mon-Fri	1	1.9%	0	0.0%
B (3am-9am) Sat, Sun	1	1.9%	1	1.8%
C (9pm-3pm) Mon-Fri	18	34.0%	9	16.4%
D (9pm-3pm) Sat	3	5.7%	4	7.3%
E (9pm-3pm) Sun	3	5.7%	4	7.3%
F (3pm-9pm) Mon-Wed	7	13.2%	5	9.1%
G (3pm-9pm) Thurs, Fri	4	7.5%	10	18.2%
H (3pm-9 pm) Sat, Sun	7	13.2%	8	14.5%
I (9pm-12Midn) Mon-Wed, Sun	1	1.9%	4	7.3%
J (9pm-12Midn) Wed-Sat	0	0.0%	7	12.7%
Unknown	8	15.1%	3	5.5%
Total	**53***	**100.0%**	**55**	**100.0%**

*Additional (other) workplace incident occurred in 'C'
**Week split into ten time periods, "A" to "J", as per McClean *et al.*(1980)

Figure 1-2: Day of the week and timing of all work cases. Values in brackets denote the proportion of known cases. *Total value for time period "I" is represented in each section.

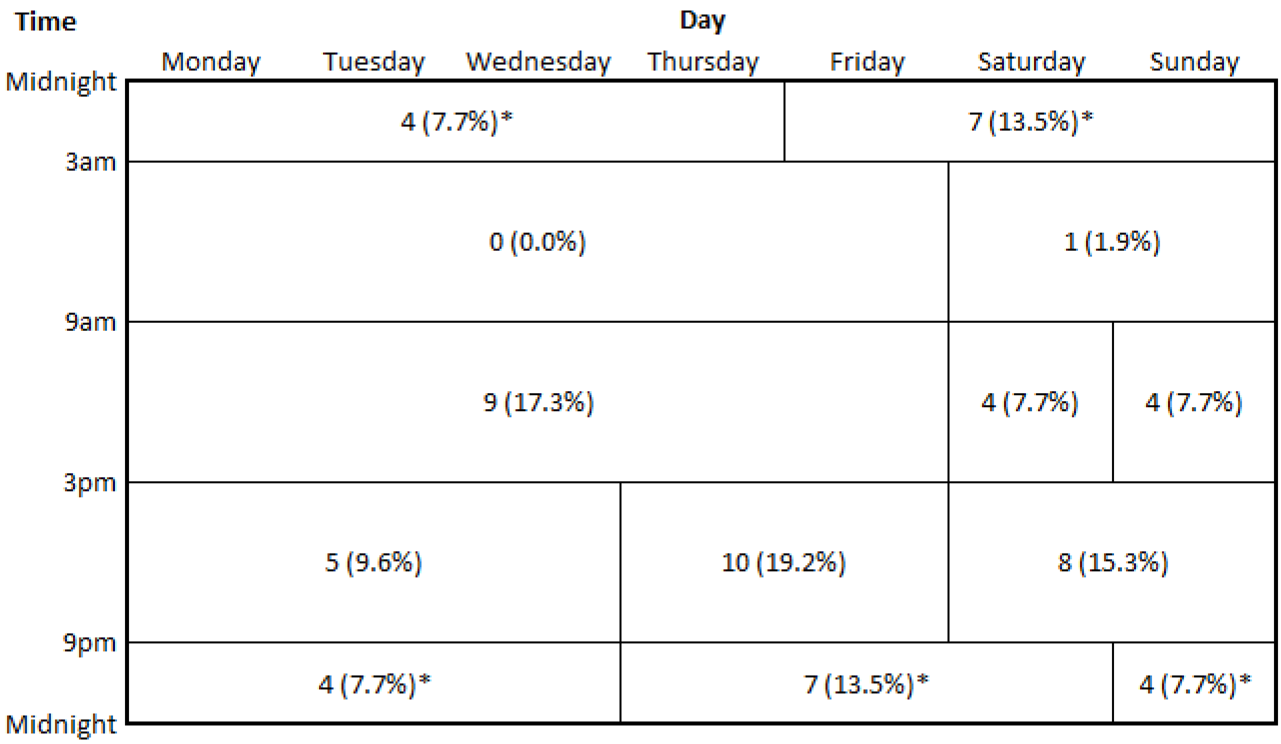

Figure 1-3: Day of the week and timing of recreational cases. *Total values for time periods "I" and "J" are represented in each section.

The interval between the incident and time of death was derived (Table 1-15). The interval bands were broad because the exact times of the incident and death were often not reported. Cases coded as less than five minutes were done with confidence around the times of the incident and death. When the interval was coded as less than one hour, the actual interval may have been only five minutes, but there was insufficient evidence for a more precise estimate. Overall, half the deaths occurred within an interval of less than an hour after the incident. In general, recreational incidents result in death immediately or within an hour. The interval between the incident and work related deaths occurred over a period up to three hours in approximately 60% of cases.

Table 1-15: Interval from incident to death by activity.

Interval from incident to death	Activity at time of crash					
	Work (53 farm and 1 other)		Recreational		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
< 5 min	11	20.4%	30	54.5%	41	37.6%
< 60 min	7	13.0%	12	21.8%	19	17.4%
< 3 hrs	14	25.9%	1	1.8%	15	13.8%
< 6 hr	10	18.5%	3	5.5%	13	11.9%
< 12 hours	5	9.3%	3	5.5%	8	7.3%
> 12 hrs	1	1.9%	5	9.1%	6	5.5%
> 24 hrs	1	1.9%	0	0.0%	1	0.9%
Unknown	5	9.3%	1	1.8%	6	5.5%
Total	**54**	**100.0%**	**55**	**100.0%**	**109**	**100.0%**

3.3.4 Vehicle & Attachments

A total of 106 of the vehicles were Quad bikes, 2 were side-by-sides and 1 was a six wheel all-terrain vehicle. The largest supplier of vehicles was Yamaha (n=35, 32.1%) followed by Honda (n=24, 22.0%) and Suzuki (n=14, 12.8%). Almost half the vehicles involved in farming incidents, were made by Honda and Yamaha (Table 1-16), with the latter being the dominant supplier of vehicles involved in recreational incidents.

Table 1-16: Make of vehicles.

Make	Activity at time of crash			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
Honda	14	26.4%	10	18.2
Yamaha	12	22.6%	23	41.8%
Polaris	8	15.1%	2	3.6%
Kawasaki	6	11.3%	4	7.3%
Suzuki	5	9.4%	8	14.5%
Bombardier	2	3.8%	1	1.8%
Barossa	0	1.9%	1	1.8%
E-Ton	1	1.9%	0	0.0%
Kazumi	0	0.0%	1	1.8%
Motoworks	0	0.0%	1	1.8%
Unknown	5	9.4%	4	7.3%
Total	**53**	**100.0%**	**55**	**100.0%**

*Additional (other) workplace incident was a Suzuki vehicle

The specific models were known in 74% of the included cases and are presented by manufacturer with model year and engine capacity in Appendix A. The model year and engine capacity was not known in sufficient cases to report in detail. The model year was known in only 20 cases with the oldest reported model year being 1987. The reported engine capacity ranged from 50 cc to 800 cc. The majority of the reported engine capacities were greater than 250 cc. The six wheeler was a 2000 model Polaris Sportsman 500 and the side-by-side vehicles were a Yamaha Rhino 700 and a Kawasaki Mule.

Many farm workers (≈45-60%) had one or more attachments on the vehicle (Table 1-17); whereas, most recreational operators did not have an attachment (≈67-75%). Recreational operators were more likely to carry a passenger than farm workers.

It is also noted that in asphyxia cases related to farms there appeared to be an over representation of cases in which it is known the Quad bike had an attachment (13 out of 22, i.e. 60%) and compared with 13 out of 37 (35%) pinned and 16 out of 54 (30%) of all workplace cases.

Table 1-17: Vehicle attachments, passengers and trailers.

Attachments/passengers/trailers	Activity at time of crash					
	Work (All)		Recreation		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Front attachment	3	5.6%	0	0.0%	3	2.8%
Rear attachment	13	24.1%	2	3.6%	15	13.8%
Front & rear attachments	7	13.0%	0	0.0%	7	6.4%
Rear attachment & trailer	1	1.9%	0	0.0%	1	0.9%
Rear passenger only	1	1.9%	10	18.2%	11	10.1%
Passenger & attachment	0	0.0%	1	1.8%	1	0.9%
Any attachment/passenger/trailer	25	46.3%	13	23.6%	38	34.9%
No attachment	15	27.8%	37	67.3%	52	47.7%
Unknown	14	25.9%	5	9.1%	19	17.4%
Total	54	100.0%	55	100.0%	109	100.0%

Only one Quad bike definitely had an operator protection device (OPD). There were two cases where the presence of an OPD was unknown and was presumed not to have been attached to the vehicle. The two included side-by-side vehicles both had roll-over protection systems (ROPS) and the six wheel Quad bike had no OPD.

3.3.5 Helmet Use

A helmet was worn in 24 cases. In four of these 24 cases, the helmet came off during the crash. Only one person involved in a farm work incident was wearing a helmet at the time. In the other 85 cases, a helmet was definitely not worn.

3.3.6 Crash characteristics

The terrain and surface characteristics were coded from the reports and photographs (Table 1-18). Overall, a paddock (35.8%) or an unsealed road (36.7%) accounted for the majority of terrains, followed by embankment (13.8%) and beach (7.3%). Overall the terrain was uneven in 39.4% of the cases, but unknown in 27.5%. The surface was in general dirt (34.9%) or grass (25.7%). The surface of paddocks was largely grass, but varied state by state. The surface was dry in 40.4% of cases, wet in 13.8% and unknown in the rest. Incidents occurred roughly equally on the flat or a slope.

For work incidents, the majority of crashes occurred in paddocks or unsealed roads and on a slope (55.6%).

Table 1-18: Crash characteristics - Terrain and surface.

Field	Coding	Activity at time of crash					
		Work (53 farm and 1 other)		Recreational		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
Terrain (main)	Beach	0	0.0%	8	14.5%	8	7.3%
	Embankment	10	18.5%	5	9.1%	15	13.8%
	Garage	0	0.0%	1	1.8%	1	0.9%
	Paddock	30	55.6%	9	16.4%	39	35.8%
	Quarry	0	0.0%	1	1.8%	1	0.9%
	Sealed Road	0	0.0%	2	3.6%	2	1.8%
	Unsealed Road	14	25.9%	26	47.3%	40	36.7%
	Vehicle Park	0	0.0%	3	5.5%	3	2.8%
Terrain (secondary)	Level	7	13.0%	29	52.7%	36	33.0%
	Uneven	29	53.7%	14	25.5%	43	39.4%
	Unknown	18	33.3%	12	21.8%	30	27.5%
Surface	Concrete	0	0.0%	2	3.6%	2	1.8%
	Dirt	15	27.8%	23	41.8%	38	34.9%
	Grass	20	37.0%	8	14.5%	28	25.7%
	Gravel	3	5.6%	8	14.5%	11	10.1%
	Ploughed	2	3.7%	0	0.0%	2	1.8%
	Rocky	4	7.4%	0	0.0%	4	3.7%
	Sand	0	0.0%	9	16.4%	9	8.3%
	Unknown	10	18.5%	5	9.1%	15	13.8%
Surface Condition	Dry	21	38.9%	23	41.8%	44	40.4%
	Unknown	30	55.6%	20	36.4%	50	45.9%
	Wet	3	5.6%	12	21.8%	15	13.8%
Slope	Flat	12	22.2%	28	50.9%	40	36.7%
	Slope	30	55.6%	19	34.5%	49	45.0%
	Unknown	12	22.2%	8	14.5%	20	18.3%

The factors that were considered to have been the immediate initiator of each crash were coded. This is separate to the cause of the injuries and required a level of interpretation of the overall case file, e.g. witness statements, police reports and photographs. Each incident had its own unique set of factors; however, an attempt was made to condense these into a set of descriptors. For example, in some cases the operator collided with an object in the environment, e.g. boom gate, wire fence or pipe. In other cases the vehicle collided with an object. Many crashes involved loss of control often because of factors such as speed, turning (on a road or in a paddock) or hitting an object that perturbed the vehicle's motion. In some cases, the operator rode off an edge and fell. The exact speed or a usable speed estimate was, however, not reported in 97 of the included cases and in the other cases was based on witness statements or descriptors such as "fast" or "high speed".

In the sample of 109 cases the two main 'initiators' were "loss of control caused by object" (19.3%) and "loss of control on slope" (18.3%) (Table 1-19). For all work related crashes "loss of control caused by object" (20.4%) and "loss of control on slope" (27.8%) were the two most frequently coded crash initiators. In comparison, there were fewer recreational crashes in which a slope was involved; however, crashes initiated by turning were more common in recreational cases. For some cases, there was more than one initiator, e.g. an operator lost control on a slope because the vehicle hit an object (11.3% of farm work cases).

Table 1-19: Initiator of crash by activity.

Initiator	Activity at time of crash					
	Farm work		Recreational		All	
	Number	Percentage	Number	Percentage	Number	Percentage
QB ridden over edge and fall	0	0.0%	2	3.6%	2	1.8%
Loss of control during jump	0	0.0%	1	1.8%	1	0.9%
Loss of control caused by object	10	18.9%	10	18.2%	21*	19.3%
Loss of control involving speed and object	1	1.9%	4	7.3%	5	4.6%
Loss of control in reverse	1	1.9%	0	0.0%	1	0.9%
Skylarking	0	0.0%	2	3.6%	2	1.8%
Loss of control on slope	15	28.3%	5	9.1%	20	18.3%
Loss of control on slope with object	6	11.3%	3	5.5%	9	8.3%
Loss of control primarily speed	0	0.0%	3	5.5%	3	2.8%
Loss of control while turning	2	3.8%	6	10.9%	8	7.3%
Loss of control in turn with object	0	0.0%	4	7.3%	4	3.7%
Loss of control - unknown	5	9.4%	3	5.5%	8	7.3%
Operator collided with object	1	1.9%	3	5.5%	4	3.7%
Initiated by other object, not collision	0	0.0%	1	1.8%	1	0.9%
Vehicle collided with object	4	7.5%	6	10.9%	10	9.2%
Unknown	8	15.1%	2	3.6%	10	9.2%
Total	**53**	**100.0%**	**55**	**100.0%**	**109**	**100.0%**

*Includes 'other' work case.

The vehicle rolled in 77 of the 109 cases. The vehicle may have rolled in more cases; however, this was not reported or central to either the crash characteristics or injury outcome. In some cases the vehicle did not roll. For example, operators were knocked off the Quad bike and the vehicle moved away until it stopped. In other cases the operator was ejected and the vehicle may have rolled, but its final orientation was not reported or photographed.

Overall there were 11 (10.1%) forward rolls, 32 (29.4%) lateral rolls, 5 (4.6%) rearward rolls, 29 (26.6%) cases with an unknown roll direction (Table 1-20) and 32 (29.4%) no rollover cases. In 15 (13.8%) cases the vehicle landed on its side, 5 (4.6%) landed on the wheels, 10 (9.2%) landed in an inverted position and in 47 cases (43.1%) the final position was not recorded or reported by witnesses. Table 1-16 presents the distribution of rollovers by direction and final position.

Table 1-20: Roll direction for all rollover cases.

Roll direction	Landed on side		Landed on wheels		Landed inverted		Unknown	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Forward Roll	0	0.0%	3	60.0%	2	20.0%	6	12.8%
Lateral Roll	15	100.0%	0	0.0%	7	70.0%	10	21.3%
Rearward Roll	0	0.0%	1	20.0%	1	10.0%	3	6.4%
Unknown direction	0	0.0%	1	20.0%	0	0.0%	28	59.6%
Total	**15**	**100.0%**	**5**	**100.0%**	**10**	**100.0%**	**47**	**100.0%**

Forty six (46) of the 54 (85.2%) work related crashes involved a rollover (Table 1-21) compared to 31 of the 55 (56.4%) recreational crashes. The final position of the vehicle was not known in the majority of cases. More fatal rollovers occurred on slopes than level ground (Table 1-22). Over half (28 of 46) of the work rollovers occurred on a slope. In contrast, rollovers occurred almost equally on level terrain or slopes in recreational crashes.

Table 1-21: Roll direction for all farm work rollover cases.

Roll direction	Landed on side		Landed on wheels		Landed inverted		Unknown	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Forward Roll	0	0.0%	2	66.7%	1	16.7%	1	3.6%
Lateral Roll	9	100.0%	0	0.0%	5	83.3%	9	32.1%
Rearward Roll	0	0.0%	1	33.3%	0	0.0%	1	3.6%
Unknown direction	0	0.0%	0	0.0%	0	0.0%	17	60.7%
Total	**9**	**100.0%**	**3**	**100.0%**	**6**	**100.0%**	**28**	**100.0%**

Table 1-22: Association between rollover and slope.

Slope	Vehicle rolled over	Activity at time of crash					
		Work (farm and other)		Recreational		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
Flat	Yes	7	58.3%	16	57.1%	23	57.5%
	No	5	41.7%	12	42.9%	17	42.5%
Slope	Yes	28	93.3%	14	77.8%	42	87.5%
	No	2	6.7%	5	22.2%	6	12.5%
Unknown	Yes	11	91.7%	1	12.5%	12	60.0%
	No	1	8.3%	7	87.5%	8	40.0%

The association between slope, attachments and rollover were examined for the farm work and recreational cases (Table 1-23 and Table 1-24, respectively). A minimum of 17 of the 28 (60.7%) work rollover crashes on a slope involved some form of attachment.

Table 1-23: Association between rollover, slope and attachments for farm work cases.

Slope	Vehicle attachments (object or passenger)	Vehicle rolled		Vehicle did not roll	
		Number	Percentage	Number	Percentage
Flat	Any attachment/passenger/trailer	3	42.9%	1	20.0%
	No Attachment	4	57.1%	4	80.0%
	Unknown	0	0.0%	0	0.0%
Slope	Any attachment/passenger/trailer	17	60.7%	1	50.0%
	No Attachment	4	14.3%	0	0.0%
	Unknown	7	25.0%	1	50.0%
Unknown	Any attachment/passenger/trailer	3	27.3%	0	0.0%
	No Attachment	2	18.2%	1	100.0%
	Unknown	6	54.5%	0	0.0%

Table 1-24: Association between rollover, slope and attachments for recreational cases.

Slope	Vehicle attachments (object or passenger)	Vehicle rolled		Vehicle did not roll	
		Number	Percentage	Number	Percentage
Flat	Any attachment/passenger/trailer	4	33.3%	1	6.3%
	No Attachment	7	58.3%	15	93.8%
	Unknown	1	8.3%	0	0.0%
Slope	Any attachment/passenger/trailer	1	25.0%	5	35.7%
	No Attachment	3	75.0%	7	50.0%
	Unknown	0	0.0%	2	14.3%
Unknown	Any attachment/passenger/trailer	2	28.6%	0	0.0%
	No Attachment	3	42.9%	1	100.0%
	Unknown	2	28.6%	0	0.0%

3.4 Included Cases (B) - Cause of Death and Injury Mechanism

3.4.1 Cause of Death

The cause of death in each case was determined by the coroner (Table 1-25). In addition to the cause of death, the deceased may have suffered other injuries that were not fatal. The head (31%) and chest (38%) accounted for the majority of fatal injuries by body region. There were 15 multi-body region deaths; in some cases these included chest and abdomen only injuries and others included head, neck and chest injuries. Asphyxia has been coded by the body region most associated with the cause of asphyxia as per the autopsy; e.g. if the chest was crushed, chest was the body region and if the neck was compressed, neck was the body region. There were thirteen fatal neck (including cervical spine) injuries.

When the fatal injuries are considered by activity, there is a very clear difference. Recreational Quad bike operators died because of fatal head injuries (51%) and farm workers died because of chest injuries (60%) as well as neck injuries (17%). In contrast only 13% of farm workers died from a head injury and among recreational riders 17% died from a chest injury and 7% died from a neck injury. Many of the multibody injuries involved chest injuries. Asphyxia cases were coded by the associated body region. For example, a person who was pinned by a Quad bike with the vehicle sitting on his chest, this was classified as a 'chest' injury from the perspective of body region. In many cases there were concomitant injuries, e.g. rib fractures and asphyxia. A single case of positional asphyxia was coded because unlike other asphyxia cases, there was no clear associated body region and it was not a multibody injury. There was one case with an unknown cause of death. The person had been pinned by the Quad bike, but was retrieved alive but then died suddenly almost immediately after being removed from under the vehicle.

Table 1-25: Cause of death (body region) by activity at time of crash.

Cause of death - body region	Activity at time of crash					
	Work (farm and other)		Recreational		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Head	7	13.0%	27	49.1%	34	31.2%
Neck*	9	16.7%	4	7.3%	13	11.9%
Chest	32	59.3%	9	16.4%	41	37.6%
Abdomen	1	1.9%	2	3.6%	3	2.8%
Thigh	0	0.0%	1	1.8%	1	0.9%
Multibody	4	7.4%	11	20.0%	15	13.8%
Not Injury	0	0.0%	0	0.0%	0	0.0%
Positional Asphyxia	0	0.0%	1	1.8%	1	0.9%
Unknown	1	1.9%	0	0.0%	1	0.9%
Total	**54**	**100.0%**	**55**	**100.0%**	**109**	**100.0%**

*Neck region includes the cervical spine.

In the sample of included and excluded cases, there were 32 cases of asphyxia, three cases of asphyxia related to drowning, three cases in which a crushing load caused blood vessel and/or airway occlusion and one case in which the cause of asphyxia was unknown (Table 1-26). Four asphyxia cases were among those excluded from the analyses. Therefore, in the included cases there were 28 (25.7%) cases of death by asphyxia, three by a combination of asphyxia and drowning, three crush related deaths related to vascular system obstruction and one unknown cause of death.

When the activity at time of death was considered, almost half the farm work deaths were caused by asphyxia or a related injury. In contrast, only approximately 15% of the recreational deaths were caused by asphyxia. It is also noted that in asphyxia cases related to farms there appeared to be an over representation of cases in which it is known the Quad bike had an attachment (13 out of 22, i.e. 60%) and compared with 13 out of 37 (35%) pinned and 16 out of 54 (30%) of all workplace cases.

Table 1-26: Cause of death (asphyxia) by activity at time of crash.

Asphyxia	**Activity at time of crash**					
	Work (farm and other)		**Recreational**		**Total**	
	Number	**Percentage**	**Number**	**Percentage**	**Number**	**Percentage**
CoD - Asphyxia	22	40.7%	6	10.9%	28	25.7%
CoD - Asphyxia (Drowning)	1	1.9%	2	3.6%	3	2.8%
Not asphyxiated - crushing related vascular CoD or other	3	5.6%	0	0.0%	3	2.8%
CoD - Not Asphyxiated	27	50.0%	47	85.5%	74	67.9%
Asphyxia (Unknown)	1	1.9%	0	0.0%	1	0.9%
Total	**54**	**100.0%**	**55**	**100.0%**	**109**	**100.0%**

3.4.2 Pattern of injury severity

The most severe injuries for the cranium, cervical spine (including the cervical spinal cord), thorax (including ribs and organs, but excluding the spine) and abdomen were coded for severity according to the Abbreviated Injury Scale (AIS) severity, *i.e.* MAIS (Table 1-27, Figure 1-4). In some cases there were multiple injuries of the same severity to the cranium or chest, e.g. severe skull fracture and severe brain injury, the MAIS in these cases is the maximum severity not a combination of severities. MAIS does not directly relate to the injury that was causal to the fatality; however, AIS severities of four and greater were associated with fatal outcomes. For example, a person may have had an MAIS cranial injury of four, but the cause of death may have been a fatal chest injury.

Table 1-27: MAIS distribution by activity at time of crash.

Body Region	MAIS	Activity at time of crash					
		Work (farm and other)		Recreational		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
Head (Cranium)	0	42	77.8%	18	32.7%	60	55.0%
	1	1	1.9%	0	0.0%	1	0.9%
	2	0	0.0%	1	1.8%	1	0.9%
	3	1	1.9%	1	1.8%	2	1.8%
	4	4	7.4%	9	16.4%	13	11.9%
	5	4	7.4%	14	25.5%	18	16.5%
	6	1	1.9%	11	20.0%	12	11.0%
	9	1	1.9%	1	1.8%	2	1.8%
CS and SC	0	46	85.2%	47	85.5%	93	85.3%
	1	0	0.0%	0	0.0%	0	0.0%
	2	1	1.9%	3	5.5%	4	3.7%
	3	1	1.9%	0	0.0%	1	0.9%
	4	0	0.0%	1	1.8%	1	0.9%
	5	0	0.0%	0	0.0%	0	0.0%
	6	2	3.7%	4	7.3%	6	5.5%
	9	4	7.4%	0	0.0%	4	3.7%
Thorax	0	24	44.4%	27	49.1%	51	46.8%
	1	0	0.0%	1	1.8%	1	0.9%
	2	4	7.4%	3	5.5%	7	6.4%
	3	13	24.1%	9	16.4%	22	20.2%
	4	7	13.0%	8	14.5%	15	13.8%
	5	4	7.4%	3	5.5%	7	6.4%
	6	1	1.9%	4	7.3%	5	4.6%
	9	1	1.9%	0	0.0%	1	0.9%
Abdomen	0	48	88.9%	42	77.8%	90	83.3%
	1	0	0.0%	0	0.0%	0	0.0%
	2	2	3.7%	5	9.3%	7	6.5%
	3	1	1.9%	0	0.0%	1	0.9%
	4	3	5.6%	5	9.3%	8	7.4%
	5	0	0.0%	2	3.7%	2	1.9%
	6	0	0.0%	0	0.0%	0	0.0%
	9	0	0.0%	0	0.0%	0	0.0%

The recreational cases tended to have higher severity MAIS scores (3 to 6) for the head in comparison to work cases. Approximately sixty percent (60%) of the head injuries amongst recreational cases were MAIS severity 4 to 6. In contrast, only less than 20% of work related head injuries were in the severity range MAIS 4 to 6. The proportion of MAIS 6 and 9 cervical spine and spinal cord cases were similar for the work and recreational groups. However, the majority of both groups suffered no cervical or spinal cord injury (85%). Both the work and recreation cases had similar MAIS severity score distributions for the thorax, with injuries in the recreational group being slightly more severe. A slightly smaller proportion of the work group suffered an abdominal injury compared to the recreational group, although in total 83% suffered no abdominal injury. The recreational group had approximately twice as many cases of MAIS severity (3 to 6) for the abdomen.

The results demonstrate that the mean and median MAIS values for the head were the greatest compared to the other body regions (Table 1-28). There was a significantly higher mean MAIS for the cranium for recreational operators compared to farm workers. Although the MAIS mean and median values for the chest were greater for farm workers compared to recreational operators, this was not a significant difference. Caution is required when considering descriptive statistics for MAIS because some injuries are coded "9" which may skew the statistics.

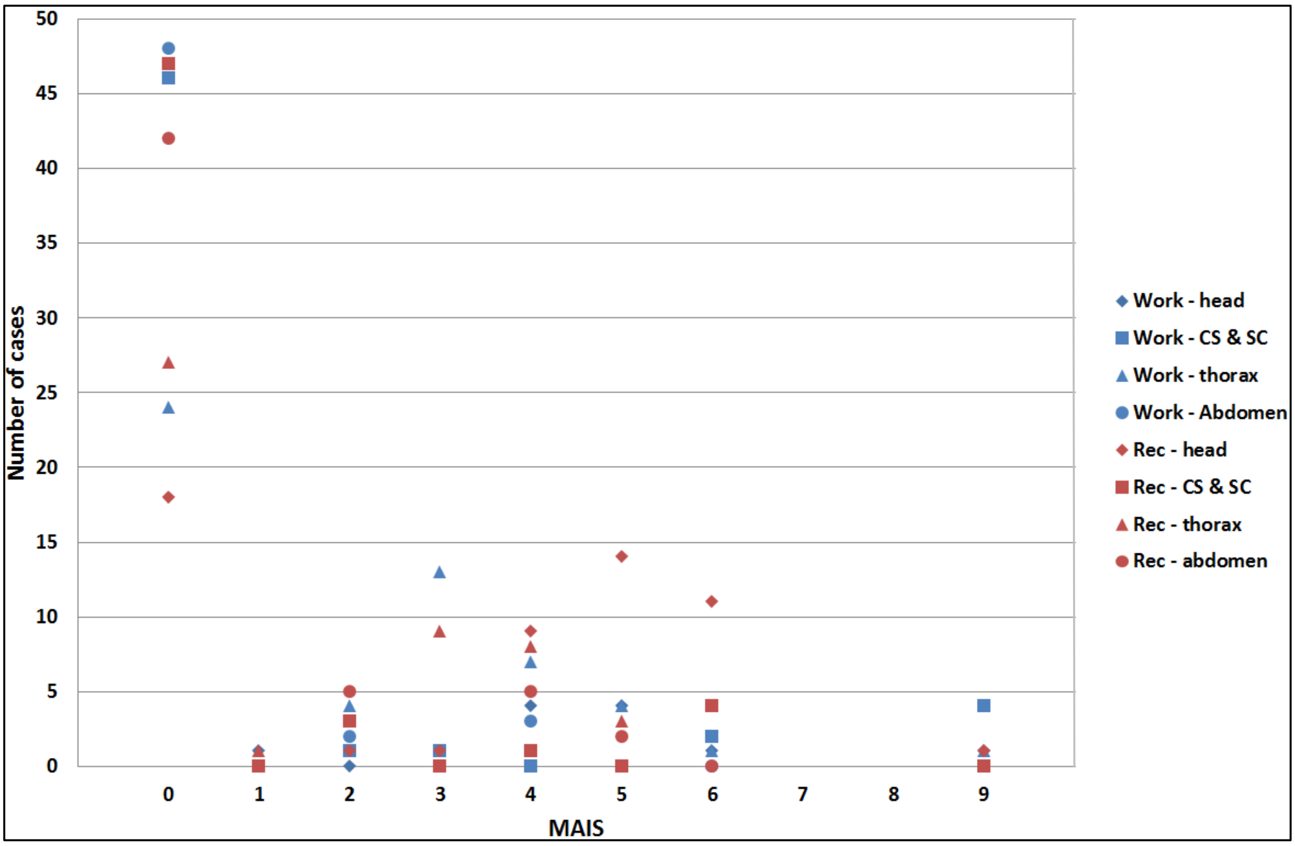

Figure 1-4: MAIS Severity for the cranium, cervical spine, thorax and abdomen by activity at time of crash.

Table 1-28: Injury severity for the by activity at time of crash.

Body Region	Activity at time of crash					
	Work (farm and other)		Recreational		Total	
	Mean	Median	Mean	Median	Mean	Median
MAIS Head (Cranium)	1.02	0.00	3.38	4.00	2.21	0.00
MAIS CS and SC	0.98	0.00	0.62	0.00	0.80	0.00
MAIS Thorax	2.04	2.00	1.91	1.00	1.97	2.00
MAIS Abdomen	0.35	0.00	0.74	0.00	0.55	0.00

Note: the mean and median are influenced by the coding of some injuries as “9”. A comparison of means using a two-sided test and assuming equal variances with a significance level .05 showed a significant difference in the mean MAIS for the cranium between work and recreational operators.

Cases in which there were at least two body regions each with at least one injury greater than MAIS 3 (Serious) severity injury or were enumerated. Reworded this means that there were two body regions each with at least one severe injury. There was only a small difference in the pattern of multibody MAIS severity injury greater than three (Table 1-29). Recreational crashes had twice (n=11) as many cases with at least two regions (cranium, cervical spine (and spinal cord), thorax and abdomen) each with a severity of at least four compared to work (n=5).

Table 1-29: Multibody MAIS Severity greater than three by activity at time of crash.

Body region distribution of MAIS > 3	Activity at time of crash			
	Work (53 farm and 1 other)		Recreational	
	Number	Percentage	Number	Percentage
No more than one region with MAIS > 3	49	90.7%	43	78.2%
Two or more regions with MAIS > 3	5	9.3%	11	20.0%
Unknown	0	0.0%	1	1.8%
Total	**54**	**100.0%**	**55**	**100.0%**

3.4.3 Mechanism of fatal injury

The mechanism of the fatal injury was coded as: impact, crush or a combination (crush-impact). This refers to a more biomechanical perspective on injury mechanisms. Some interpretation of the complete documentation provided this classification. For example, a person ejected at speed who hit his head against a tree suffered an impact injury. A person who was subjected to crush forces beneath the vehicle but without extensive impact related injuries, e.g. a flail chest, was classified as crush. In some cases it was reported that a person was ejected, collided with a tree and that they were subjected to crush forces acting between the vehicle and the tree. The mechanism of injury for a person with a combination of injuries related to crush and impact was labelled accordingly (Table 1-30). The dominant injury mechanism for farm workers was crush (62.3%). In contrast, the dominant injury mechanism for recreational operators was impact (63.6%).

Table 1-30: Mechanism of injury by activity at time of crash.

Mechanism	Activity at time of crash			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
Crush	33	62.3%	9	16.4%
Crush/impact	7	13.2%	11	20.0%
Impact	11	20.8%	35	63.6%
Drowning	1	1.9%	0	0.0%
Unknown (crush related)	1	1.9%	0	0.0%
Total	**52**	**100.0%**	**55**	**100.0%**

*Additional (other) workplace was coded 'Impact'.
Note: The following farm work case drowning (pinned) was excluded.
Therefore Farm work cases = 53, Work (other) = 1 and Recreational = 55.

The body region associated with the cause of death was examined with regards to activity and mechanism of the fatal injury (Table 1-31). In general crush type fatal chest injuries are more prevalent for farm workers whereas recreational riders suffer impact related head injuries.

Table 1-31: Mechanism by body region and activity.

Activity	Body region	Cause of death					
		Crush		Crush/impact		Impact	
		Number	Percentage	Number	Percentage	Number	Percentage
Farm work	Head	1	3.0%	1	14.3%	5	45.5%
	Neck	3	9.1%	1	14.3%	5	45.5%
	Chest	29	87.9%	3	42.9%	0	0.0%
	Abdomen	0	0.0%	1	14.3%	0	0.0%
	Thigh	0	0.0%	0	0.0%	0	0.0%
	Multi-body	0	0.0%	1	14.3%	1	9.1%
	Other	0	0.0%	0	0.0%	0	0.0%
Recreation	Head	2	22.2%	5	45.5%	20	57.1%
	Neck	0	0.0%	1	9.1%	3	8.6%
	Chest	6	66.7%	2	18.2%	1	2.9%
	Abdomen	0	0.0%	1	9.1%	1	2.9%
	Thigh	0	0.0%	0	0.0%	1	2.9%
	Multi-body	0	0.0%	2	18.2%	9	25.7%
	Other	1	11.1%	0	0.0%	0	0.0%

Note: The following three work cases have been excluded from this table: work-other; drowning (pinned); unknown cause.
Therefore Farm work cases = 52 and Recreational = 55.

3.4.4 Helmet use and injury

In 24 of the included cases a helmet was worn (Table 1-32). In four of these cases the helmet came off during the crash. In six cases where a helmet had been worn, head injury was the cause of death and in nine cases multibody injury was the cause of death (Table 1-33).

Table 1-32: Helmet use by activity at time of crash.

Mechanism	Activity			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
No helmet	52	98.1%	33	60.0%
Helmet - remained on	1	1.9%	18	32.7%
Helmet - ejected	0	0.0%	4	7.3%
Total	**53**	**100.0%**	**55**	**100.0%**

*Additional (other) workplace was coded 'Helmet – remained on'.

Table 1-33: Head, neck and multibody injury by helmet use.

Body region	Helmet Use					
	No helmet		Helmet - remained on		Helmet - ejected	
	Number	Percentage	Number	Percentage	Number	Percentage
Head	28	60.9%	4	33.3%	2	50.0%
Neck	12	26.1%	1	8.3%	0	0.0%
Multi-body	6	13.0%	7	58.3%	2	50.0%
Total	**46**	**100.0%**	**12**	**100.0%**	**4**	**100.0%**

There was a non-significant difference between the mean MAIS for the head and cervical spine plus spinal cord based on helmet use. The MAIS for the head and cervical spine were lower if a helmet had been worn and stayed on during the crash (Table 1-34). The total number of cases in which helmets were worn is very low.

Table 1-34: MAIS severity for the cranium and cervical spine by helmet use.

Body Region	Helmet not worn			Helmet worn			Helmet ejected during crash		
	Mean	Median	Maximum	Mean	Median	Maximum	Mean	Median	Maximum
MAIS Head (Cranium)	2.21	0.00	9.00	1.70	0.00	5.00	4.75	4.50	6.00
MAIS CS and SC	0.86	0.00	9.00	0.70	0.00	6.00	0.00	0.00	0.00

Note: the mean and median are influenced by the coding of some injuries as "9".

3.4.5 Operator pinned and injury

Fifty-five (50.5%) of the deceased riders were pinned by the Quad bike (Table 1-35). “Pinned” means that the person was prevented from freeing themselves and compressed between the vehicle and ground until they were released by another person. In most case, they person was released post mortem. Whether the person was pinned was ascertained from a combination of records, e.g. police and witness statements. A higher proportion of farm workers (37, 69.8%) were pinned under the Quad bike than recreational riders (18, 32.7%), which reflects the activities and speeds involved, as well as the potential for farm workers to operate in isolation compared to recreational Quad bike operators. Many of the deceased recreational operators had been riding with friends.

Table 1-35: Pinned by activity at time of crash.

Mechanism	Activity at time of crash			
	Farm work		Recreation	
	Number	Percentage	Number	Percentage
Pinned	37	69.8%	18	32.7%
Not pinned	16	30.2%	37	67.3%
Total	**53**	**100.0%**	**55**	**100.0%**

*Additional (other) workplace was coded ‘Not pinned’.

All 28 cases of asphyxia involved the deceased being pinned under the Quad bike (Table 1-36). In two of the three asphyxia (drowning) cases, the operator was pinned by the Quad bike as well as all other crushing (vascular or other) cases. Not all pinned operators were asphyxiated. Approximately 30% of the farm workers and 56% of recreational operators who were pinned were not asphyxiated. This might reflect the size of the Quad bike and the immediate presence of others who could move the vehicle off the operator.

Table 1-36: Asphyxia by pinned and activity at time of crash. (work-other case excluded)

Mechanism	Activity at time of crash							
	Farm work				Recreation			
	Pinned		Not pinned		Pinned		Not pinned	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Asphyxia	22	59.5%	0	0.0%	6	33.3%	0	0.0%
Asphyxia - drowning	0	0.0%	1	6.3%	2	11.1%	0	0.0%
Asphyxia - unknown	1	2.7%	0	0.0%	0	0.0%	0	0.0%
Not asphyxia - crush related	3	8.1%	0	0.0%	0	0.0%	0	0.0%
Not asphyxia	11	29.7%	15	93.8%	10	55.6%	37	100.0%
Total	**37**	**100.0%**	**16**	**100.0%**	**18**	**100.0%**	**37**	**100.0%**

As the speed of the crash increases, it is more likely that the rider will be ejected, because they are not restrained on the vehicle, and interact with the environment. In the lower speed farm crashes, the Quad bike, sometimes with accessories and/or cargo, rolls onto the rider during the crash. In

27 of the 37 (73%) farm work pinned cases, the cause of death was chest injury and in six cases (16%) it was neck injury (Table 1-37). The deceased person involved in the work–other activity was not pinned. It is also noted that in asphyxia cases related to farms there appeared to be an over representation of cases in which it is known the Quad bike had an attachment (13 out of 22, i.e. 60%) and compared with 13 out of 37 (35%) pinned and 16 out of 54 (30%) of all workplace cases.

Table 1-37: Injured body region by activity at time of crash.

Injured body region	Activity at time of crash							
	Farm work				Recreation			
	Pinned		Not pinned		Pinned		Not pinned	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Head	1	2.7%	6	37.5%	5	27.8%	22	59.5%
Neck	6	16.2%	3	18.8%	2	11.1%	2	5.4%
Chest	27	73.0%	5	31.3%	7	38.9%	2	5.4%
Abdomen	1	2.7%	0	0.0%	0	0.0%	2	5.4%
Thigh	0	0.0%	0	0.0%	0	0.0%	1	2.7%
Multi-body	1	2.7%	2	12.5%	3	16.7%	8	21.6%
Other	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Unknown	1	2.7%	0	0.0%	0	0.0%	0	0.0%
Positional asphyxia	0	0.0%	0	0.0%	1	5.6%	0	0.0%
Total	**37**	**100.0%**	**16**	**100.0%**	**18**	**100.0%**	**37**	**100.0%**

Note: Single work-other case excluded.

The pattern of injury severity by activity and whether the operator was pinned was examined. The farm workers who were pinned had a mean head MAIS of 0.49 and mean cervical spine MAIS of 0.73 which were the lowest for the four combinations of activity and pinned (Table 1-38). The mean and median MAIS for the thorax were the highest for those who were pinned while undertaking farm work.

Table 1-38: MAIS severity by activity and pinned.

Body Region	Activity at time of crash											
	Farm work						Recreational					
	Pinned			Not pinned			Pinned			Not pinned		
	Mean	Median	S.D.	Mean	Median	S.D.	Mean	Median	S.D.	Mean	Median	S.D.
MAIS Head (Cranium)	0.49	.00	1.39	2.31	0.00	2.91	1.56	0.00	2.15	4.27	5.00	2.28
MAIS CS and SC	0.73	.00	2.28	1.63	0.00	3.26	1.00	0.00	2.09	0.43	.00	1.42
MAIS Thorax	2.00	2.00	2.09	2.00	1.00	2.25	1.78	1.00	1.93	1.97	1.00	2.22
MAIS Abdomen	0.32	0.00	1.00	.19	.00	.75	.56	0.00	``1.34	0.83	.00	1.59

Note: the mean and median are influenced by the coding of some injuries as “9”. Single work-other case excluded, which was a “not pinned” case.

3.4.6 Distribution of Injuries

The distribution of injuries by body region, including non-fatal injuries, was analysed (Table 1-39). This contains more descriptive fields for the anatomical region injured, although the severities of those injuries were not coded, except as the maximum AIS for the overall body region as presented in the report.

Overall, brain trauma occurred in almost half (44%) of all cases and skull fracture in approximately one third (32%) of all cases. However, when head injuries are considered by activity, 11% of farm workers suffered a skull fracture compared to 53% of recreational riders, and 21% of farm workers suffered a brain injury compared to 67% of recreational riders. Therefore, major head injury is a significant risk in fatal recreational Quad bike crashes and less so in farm work.

Cervical spinal fractures or dislocations occurred in 15 cases; seven farm workers and eight recreational riders. Cervical spinal cord injury occurred in 8 cases; three farm workers and five recreational riders.

Thoracic fractures (including ribs, sternum, clavicle and scapula) occurred in 44% of all cases, with slightly more than half being unilateral and less than half bilateral fractures. The clavicle and scapula were included with other thorax fractures because of their location and the implication in terms of body contact; it is recognised that these are functionally part of the shoulder and upper limb. Lungs and associated vessel injuries were present in 38% of all cases and the abdominal organs were injured in 16% of all cases. Half of farm workers had thoracic fractures compared to approximately 40% of recreational riders. Heart and lung injury distributions by activity were similar.

Abdominal and pelvic injuries were infrequent. It is interesting to note that there were virtually no upper or lower extremity fractures. This contrasts to motorcyclist injury patterns. In one case the recreational rider was impaled by the handlebar, an impact, causing a major blood vessel laceration in this thigh.

Thoraco-lumber fractures occurred in only six cases. There were no lumbar or thoracic spinal cord injuries.

Table 1-39: Region and type of injuries by activity at time of crash.

Anatomical Group and Injury Type		Activity at time of crash					
		Farm work		Recreational		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
Skull Injury	Skull fractures	6	11.3%	29	52.7%	35	32.4%
	No skull fractures	47	88.7%	26	47.3%	73	67.6%
Brain Injury	Traumatic Brain Injury	11	20.8%	37	67.3%	48	44.4%
	No TBI	42	79.2%	18	32.7%	60	55.6%
Cervical Vertebral (C-V) Injury	C-V Fracture/Dislocation	7	13.2%	8	14.5%	15	13.9%
	No fracture	46	86.8%	45	81.8%	91	84.3%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Cervical Spinal Cord	Cervical Spinal Cord Injury	3	5.7%	5	9.1%	8	7.4%
	No SCI	46	86.8%	46	83.6%	92	85.2%
	Not Recorded or Unknown	4	7.5%	4	7.3%	8	7.4%
Sternal, rib, clavicle or scapula fractures	Unilateral fractures	15	28.3%	12	21.8%	27	25.0%
	Multiple bilateral fractures	12	22.6%	8	14.5%	20	18.5%
	No fractures	26	49.1%	33	60.0%	59	54.6%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Heart + vessels injury	Heart or vessel injury	5	9.4%	6	10.9%	11	10.2%
	No Heart or vessel injury	48	90.6%	47	85.5%	95	88.0%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Lung + vessels injury	Lung or vessel injury	18	34.0%	23	41.8%	41	38.0%
	Lung Signs of Asphyxia	12	22.6%	3	5.5%	15	13.9%
	No Lung or vessel injury	23	43.4%	28	50.9%	51	47.2%
	Not Recorded or Unknown	0	0.0%	1	1.8%	1	0.9%
Abdominal Organ Injury	Abdominal Organ Injury	5	9.4%	12	21.8%	17	15.7%
	No Abdominal Organ Injury	48	90.6%	41	74.5%	89	82.4%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Pelvic Fracture	Fracture/Dislocation	0	0.0%	1	1.8%	1	0.9%
	No Pelvic Fracture	53	100.0%	52	94.5%	105	97.2%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Pelvic Organ Injury	No Pelvic Organ Injury	53	100.0%	53	96.4%	106	98.1%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Thoracic and Lumbar (T-L) Vertebrae	T-L Vertebral Fracture	2	3.8%	4	7.3%	6	5.6%
	No T-L Vertebral Fracture	51	96.2%	49	89.1%	100	92.6%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Thoracic and Lumbar Spinal Cord	No TS/LS SCI	53	100.0%	53	96.4%	106	98.1%
	Not recorded	0	0.0%	2	3.6%	2	1.9%
	Not Recorded or Unknown	0	0.0%	0	0.0%	0	0.0%
Upper Limb Fracture	Upper Limb Fracture	1	1.9%	2	3.6%	3	2.8%
	No Upper Limb Fracture	52	98.1%	51	92.7%	103	95.4%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%
Lower Limb Fracture	Lower Limb Fracture	1	1.9%	1	1.8%	2	1.9%
	No Lower Limb Fracture	52	98.1%	52	94.5%	104	96.3%
	Not Recorded or Unknown	0	0.0%	2	3.6%	2	1.9%

Note: Single work-other case excluded.

3.4.7 Asphyxia and associated injuries

The pattern of MAIS injury severity for the cranium, cervical spine, thorax and abdomen was examined for farm workers with respect to whether they died of asphyxia or a variant (asphyxia (drowning) and vascular crushing). Table 1-40 shows that the injury severities were typically low. In one of the cases the cranial MAIS was 6, although the cause of death was given as the neck being crushed there was no cervical spine or spinal cord injury as included in the AIS coding system. The cause of death would have been coded differently using the body region "neck" in the AIS system. The vast majority of those who died of asphyxia or a similar type cause of death had no head, cervical spine or abdominal injury. Ten of the 26 had an MAIS three (serious) chest injury and two had a chest injury of severity greater than AIS three. The nature of the thoracic injuries for the asphyxia cases are presented in Table 1-41.

In the "asphyxia-unknown" case, the person suffered no cranial, cervical, thoracic or abdominal injury; this case is excluded from Table 1-40 and Table 1-41.

The pattern of injury, and in recognition that the operators were pinned by the vehicle, strongly suggests that had the operator not been pinned, many of the twenty six (26) would have survived the crash with only minor injuries.

Table 1-40: injury severity by asphyxia for farm workers by MAIS for other regions (n=26).

MAIS	Body regions							
	Head (cranium)		CS and SC		Thorax		Abdomen	
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
0	24	92.3%	25	96.2%	12	46.2%	25	96.2%
1	1	3.8%	0	0.0%	0	0.0%	0	0.0%
2	0	0.0%	0	0.0%	2	7.7%	1	3.8%
3	0	0.0%	1	3.8%	10	38.5%	0	0.0%
4	0	0.0%	0	0.0%	1	3.8%	0	0.0%
5	0	0.0%	0	0.0%	1	3.8%	0	0.0%
6	1	3.8%	0	0.0%	0	0.0%	0	0.0%
9	0	0.0%	0	0.0%	0	0.0%	0	0.0%

Note: "Asphyxia unknown" excluded.

Table 1-41: Association between Asphyxia and other thoracic injuries for farm work cases.

Anatomical Group	Injury Type	Asphyxia (n=26)	
		Number	Percentage
Sternum, rib, clavicle or scapula fractures	Unilateral fractures	7	100.0%
	Multiple bilateral fractures	6	100.0%
	Not Recorded or Unknown	0	0.0%
	No fractures	13	100.0%
Heart + vessels injury	Heart or vessel injury	2	100.0%
	No Heart or vessel injury	24	100.0%
	Not Recorded or Unknown	0	0.0%
Lung + vessels injury	Lung or vessel injury	7	100.0%
	Lung Signs of Asphyxia	12	100.0%
	No Lung or vessel injury	7	100.0%
	Not Recorded or Unknown	0	0.0%

Note: Each of the descriptors is mutually exclusive in the field, e.g. where there were lung signs of asphyxia (e.g. congestion) there were no other signs of lung injury.

4 Discussion

This study was commissioned as part of the Quad Bike Performance Project, to provide the detailed circumstances and fatal injuries related to Quad bike and Side by Side Vehicle usage in Australia, obtainable from the detailed Coronial case files.

An initial search of the NCIS dataset of fatalities in Australia between 2000 and 2012 was undertaken. This search identified 141 closed cases involving all-terrain vehicles. Full information is only available for closed cases. All available case documents in the NCIS dataset were reviewed and it was determined that the full coronial files were required. In a few cases NCIS documentation was fairly complete, but in the majority of cases the documentation was inadequate. This was a limitation raised by Lower *et al*. (2012, 2013). During and before commencement of the project four different research ethics approvals were obtained. After review of the 141 cases 32 were excluded from further analysis. Those excluded included crashes on roads with other vehicles, and vehicles that were not grouped within the terms of reference of the project, e.g. dune buggies. An extensive case series review and analysis of 109 fatal all-terrain vehicle crashes in Australia was undertaken; these are referred to as the “included” cases. The included cases are a sub sample of the 141 cases. The objectives were to describe the characteristics of fatal ATV incidents, describe the pattern of injuries, including fatal injuries, and consider the mechanisms of injury.

Data were extracted from each set of case documents and coded according to a set of fields under seven general topics: General, Temporal, Demographic, Vehicle, Environment, Crash and Injury. In total 99 fields were coded. In the majority of cases each field could be coded based on the available information to a suitable level. When the information was not available or unclear, the field was labelled as “unknown”.

NSW and Queensland were the states in which approximately half the 141 and 109 included fatal ATV incidents and crashes occurred. The deceased person was male in 82% of the 141 cases and 86% of the included 109 cases. The age of the person at the time of the incident ranged from one year to 94 years in the sample of 141 cases. The age of the person at the time of the incident ranged from four years to 94 years in the included 109 cases. In the included 109 cases the age was distributed relatively evenly between 5 years and 74 years. In work related cases 76% of the people killed were in the age group 16 to 74 years and 20% were older than 75 years. The age distribution for work related fatalities was skewed to the older age groups and for recreational to the younger age groups. The mean height and body mass for all included cases in the age group 15 to 74 years were 1.75 m and 81 kg, respectively. This compares to the mean height and body mass for the adult male USA population of 1.77 m and 83 kg, respectively. Therefore, the population in terms of age and body dimensions is representative of the normal population and should be compatible in terms of the expected vehicle ergonomic design specifications.

Fifty three (53) of 54 work related fatalities occurred during a farming activity. Of the known industry groups, dairy was the main group. Farm related incidents occurred on farms during normal farming work, e.g. mustering, spraying, transport and maintenance. The farm was also the location of many fatal recreational incidents and in total was the location for approximately three quarters of all the 109 incidents. State forests and beaches were the next most frequent locations for recreational incidents. The terrain and surfaces were consistent with the general locations. Crashes occurred on a paddock (36%) and unsealed roads (37%).

Summer was the period with the highest proportion of fatal incidents. The time of day of the incidents was distributed across the full 24 hour period, but the most common period for farm work incidents was Monday to Friday between 9 am and 3 pm (34%). The next most common grouping was between 3 pm and 9 pm on any day. Therefore, farm work related fatal incidents are often occurring during what might be considered normal working hours for the general population and not at unusual time of the day or week. In comparison, the time of day of recreational incidents are skewed towards the late afternoon and early evening, with some incidents occurring in the middle of the night.

There were 106 Quad bikes, two side-by-sides and one six wheel ATV in the sample of 109 cases. Yamaha, Honda and Suzuki were the suppliers of approximately 65% of the vehicles. The majority of the vehicles were common brands. Between approximately 45% and 60% of farm workers had some form of attachment on the vehicle. The upper limit of 60% is provided because the use of an attachment was unknown in 26% of the farm work cases. Most (67-75%) of recreational operators did not have an attachment. Only one Quad bike had an operator protection device and that was not relevant to the incident and the outcome of the crash.

What was termed “loss of control” was considered the initiator of the majority of the crashes. The term does not imply that the crash was initiated by operator error or lack of operator skill. For farm workers loss of control occurred on slopes or was caused by striking an object, e.g. a rut or a branch. There was a broad range of factors that contributed to the initiation of the crash. In contrast to loss of control, in some cases the vehicle collided with an object and in others the operator collided with an object, e.g. pipe or boom gate.

The vehicle rolled in the majority of cases and this was more likely to occur on a slope and with the use of attachments than on the flat with no attachments. The use of attachments could not be considered the primary cause of rollovers though. When the cases are considered in terms of terrain, slope and attachments, there is a very broad distribution of case groupings that makes a precise analysis of these factors combined challenging. The speed of the vehicles was largely not quantified, but the impression gained from reading the case files and in consideration for the injury patterns is that farm workers were driving at slow speeds when they rolled, whereas recreational operators were driving at high speeds when they rolled. The ratio of lateral to rearward to forward rolls (with a known roll direction) was 6.4 to 1 to 2.2.

The analyses show that the main causes of death and serious injury are head and thoracic injury, including mechanical or traumatic asphyxia. There is also a clear, but relatively small, incidence of fatal and serious cervical spine injury. The pattern of injuries is different for fatally injury farm workers and recreational riders. Therefore, safety initiatives may differ between these two groups.

There was a clear difference in the body region and type of injuries that caused the deaths of farm workers and recreational riders. The main cause of death for farm workers was chest injury (59%) compared to head injury for recreational riders (49%). Only 13% of farm workers died as a result of head injury. There was a higher proportion of multibody cause of death for recreational riders compared to farm workers, 20% to 7%, respectively. These causes of death are consistent with the crash characteristics. In the case of farm workers this typically involved being pinned by the vehicle as a result of a rollover whereas the recreational rider was typically ejected from the vehicle hit an object in the environment at high speed and/or interacted with the moving Quad bike. For example, in some cases the rider was ejected at speed, hit a tree and then was crushed by the Quad bike.

Crushing and a combination of crushing and impact were considered the mechanism of the majority of the fatal farm work injuries. In contrast an impact was considered the mechanism of the majority of recreational fatal injuries. The injuries suffered by the recreational riders were often critical or unsurvivable. For example, 45% of the head injuries suffered by recreational riders were classified as critical or unsurvivable. Recreational riders were more also slightly more likely than farm workers to have at least one severe injury at two or more body regions than farm workers. The actual descriptions of the injuries, not presented in this report, reflect the severity of the impact, e.g. lacerated aorta, flail chest and hinge fractures of the skull with massive brain injuries.

Almost half the farm work fatalities (n=26) were caused by asphyxia or a related condition. In these cases the worker was pinned under the Quad bike and typically suffered no injury to a body region other than the thorax and injuries to the thorax, e.g. fractured ribs, were classified as none in twelve case, serious in ten cases and two severe or critical. The data suggest strongly that approximately twenty of the farm workers who died of asphyxia would have survived the crash if the vehicle did not pin them with a force sufficient in terms of magnitude and duration to cause asphyxia. It is possible that a small proportion of those with a serious, severe or critical thoracic injury may have died as a consequence of those injuries if they had received appropriate medical attention in time. In the other fatal farm work cases a large proportion of those not asphyxiated were injured when the Quad bike interacted with the operator during a rollover.

The interaction of the weight and/or energy of the vehicle with the operator during a low speed crash with a rollover is the most important cause of fatal farm work injury. In contrast, the interaction of the recreational rider’s energy with unyielding elements in the natural and built environments is the primary cause of fatal recreational rider injury, coupled with the interaction of the energy of the Quad bike with the rider after the rider has been ejected. The state forest environment presents specific hazards for riders because of the densely tree lined narrow unsealed roads. If the rider loses control and is ejected it is highly probable that they will collide with a tree. These are unforgiving environments.

Farm workers were often working alone when the incident occurred. In contrast, recreational riders were often riding with or near friends. The case series analysis is limited in that near misses, e.g. when the Quad bike rolls and pins the rider but the rider is retrieved, are not included.

Although speculative, this might occur more frequently in recreational situations than farm work. The isolated nature of farm work in terms of remoteness and working alone is likely to be a contributing factor in Quad bike deaths.

Intoxication was not coded in this analysis. In general, the case reports showed that there was a level of intoxication associated with recreational crashes. In some cases, multiple contributing factors were present in recreational crashes, e.g. speed, fatigue, low light, intoxication and unfamiliar terrain. Those factors were normally not associated with farm work crashes.

Twenty four operators wore a helmet at the time of the crash. In four cases the helmet was ejected. It is presumed that AS/NZS 1698 (2006) compliant helmets were worn, but this was poorly documented in the case files. The counts are too small to perform any statistical analyses. A trend was apparent that a helmet offered some protection to the head. On an individual case basis, some riders suffered massive head injuries even when wearing a helmet. The case series analysis does not consider people who survived crashes because they were wearing a helmet. The data indicate that higher helmet wearing rates may have altered only slightly the incidence of fatal farm work related crashes because fatal head injury is not the dominant cause of death. However, consideration for injury and no-injury crashes is also required when considering helmet policies. In the context of the performance requirements of helmets, these might be different for farm workers and recreational riders. The impression gained is that recreational riders require a helmet with similar performance requirements to AS/NZS 1698 (2006) because of the high-speed nature of the impacts. In contrast, farm workers may require a helmet that offers greater crush protection than currently defined or inferred in AS/NZS 1698 (2006) or similar standards, including NZS 8600:2002 (Standards New Zealand, 2002).

One of the initial reasons for the case series review was to inform the development of crashworthiness assessments of Quad bikes. In short, the analyses indicate that reducing the propensity for the vehicle to roll, improving the handling so that loss of control events are reduced, particularly when there is a perturbation, and managing the interaction between the vehicle and the operator in a rollover are three important areas.

5 Conclusions

A case series review and analysis of 109 work and recreational ATV related deaths found that farm workers tended to suffer crush related fatal injuries when the vehicle rolled and interacted with the operator, often pinning the operator under the vehicle. In almost half the farm work fatalities the operator died of asphyxia without suffering any other severe injury. The analyses suggest strongly that had the operator not been pinned or retrieved quickly from under the vehicle, the majority of those asphyxiated would not have died. The operational conditions were typical of farm work in terms of time of day, activities, terrain and surfaces. Recreational related deaths were distinctly different to farm work deaths. Recreational riders died as a result of impact related injuries that arose when the rider was ejected after losing control of the vehicle at high speed. The analyses support the need to reduce the propensity for the vehicle to roll, to improve the handling so that loss of control events are reduced, and to prevent crush and pinning of operators, in particular farm workers, by the vehicle during and after a rollover crash.

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References

1. Lower T. Quad Bikes: Tobacco on Four Wheels. Australian and New Zealand Journal of Public Health 37 (2), pp. 105-07, 2013.
2. Lower T, Herde E, Fragar LJ. Quad Bike Deaths in Australia 2001 to 2010. Journal of Health, Safety and Environment, 28 (1), pp.7-24, 2012
3. McLean AJ, Holubowycz OT, Sandow BL. Alcohol and Crashes: Identification of Relevant Factors in this Association. Department of Transport, Office of Road Safety, Commonwealth Department of Transport. Adelaide, SA, Australia: Road Accident Research Unit, University of Adelaide, 1980.
4. Gennarelli T and Wodzin E. Abbreviated Injury Scale 2005. Barrington, IL, USA: AAAM, 2005.
5. International Organisation for Standardisation. Part 2: Statistical Summarises of Body Measurements from Individual ISO Populations. Basic Human Body Measurements for Technological Design. Geneva, Switzerland: ISO, 2010.
6. AS/NZS 1698, 2006. Protective helmets for vehicle users. Standards Australia/Standards New Zealand, Sydney/Wellington.
7. Standards New Zealand, P8600: 2002, All-Terrain Vehicle Helmets Wellington New Zealand.

Appendix A: ATV details

Vehicle	Make	Model (as described in the coronial files)	Size [cc]	Year
QB	Barossa	Unknown	50	Unknown
QB	Bombardier	800 HO	800	2007
QB	Bombardier	Outlander 800	800	Unknown
QB	Bombardier	Rotax	640	2001
QB	E-Ton	Challenger CXL-150	Unknown	Unknown
QB	Honda	400EX Quad Runner	400	Unknown
QB	Honda	Big Red	Unknown	Unknown
QB	Honda	Big Red 300R TRX300FW	300	Unknown
QB	Honda	Foreman	500	Unknown
QB	Honda	Foreman 400	400	Unknown
QB	Honda	Foreman ES	500	Unknown
QB	Honda	Fourtrax	Unknown	Unknown
QB	Honda	Fourtrax AT	Unknown	Unknown
QB	Honda	FourTrax ES (TRX350 FE)	350	Unknown
QB	Honda	Fourtrax Foreman ES 450SE	450	Unknown
QB	Honda	Fourtrax TRX400 FX	400	1999
QB	Honda	Fourtrax TRX400EX	400	Unknown
QB	Honda	TRX 250	Unknown	Unknown
QB	Honda	TRX300	300	1997
QB	Honda	TRX350FWM	350	Unknown
QB	Honda	TRX350TEY	350	Unknown
QB	Honda	TRX400	400	Unknown
QB	Honda	TRX400fa	400	Unknown
QB	Honda	TRX420FM7	420	Unknown
QB	Honda	TRX450R	450	2005
QB	Honda	Unknown	650	Unknown
QB	Honda	Unknown	350	Unknown
QB	Honda	Unknown	Unknown	Unknown
QB	Honda	Unknown	Unknown	Unknown
QB	Kawasaki	KFX 400	Unknown	Unknown
QB	Kawasaki	KLF 300	Unknown	Unknown
QB	Kawasaki	KVF Workhorse 360	360	Unknown
QB	Kawasaki	KVF360	360	2003
QB	Kawasaki	Unknown	400	Unknown
QB	Kawasaki	Unknown	Unknown	Unknown
QB	Kawasaki	Workhorse 300	300	Unknown
QB	Kawasaki	Workhorse 400	400	Unknown
QB	Kawasaki	Workhorse 400	400	Unknown
QB	Kazumi	Mini	Unknown	Unknown
QB	Motoworks	Unknown	Unknown	Unknown

Vehicle	Make	Model (as described in the coronial files)	Size [cc]	Year
QB	Polaris	3400	400	1996
QB	Polaris	Magnum 325	325	Unknown
QB	Polaris	Magnum 425	425	Unknown
QB	Polaris	Sportsman	Unknown	Unknown
QB	Polaris	Sportsman X2 500	500	2006
QB	Polaris	Trail Boss 330	330	Unknown
QB	Polaris	Twin Sportsman	Unknown	Unknown
QB	Polaris	Unknown	325	1999
QB	Polaris	Unknown	500	Unknown
QB	Suzuki	275 RVG	500	Unknown
QB	Suzuki	Kin Quad 750AXI	750	Unknown
QB	Suzuki	KingQuad	750	Unknown
QB	Suzuki	KingQuad	300	Unknown
QB	Suzuki	KingQuad LT-A700c	Unknown	Unknown
QB	Suzuki	LT 250F	250	Unknown
QB	Suzuki	LTF 250K Quad Runner	250	1989
QB	Suzuki	Quad Master 300	300	1996
QB	Suzuki	Quad Runner	500	2000*
QB	Suzuki	Quad Runner 160	Unknown	Unknown
QB	Suzuki	Quad Sport	80	Unknown
QB	Suzuki	Twin Quad 300	300	Unknown
QB	Suzuki	Unknown	500	Unknown
QB	Suzuki	Unknown	450	Unknown
QB	Yamaha	250YFM225	250	Unknown
QB	Yamaha	Banshee	350	Unknown
QB	Yamaha	Banshee 350	350	Unknown
QB	Yamaha	Banshee 350	Unknown	Unknown
QB	Yamaha	Bear Tracker	250	Unknown
QB	Yamaha	Bear Tracker	250	2001
QB	Yamaha	Big Bear	250	Unknown
QB	Yamaha	Big Bear	350	Unknown
QB	Yamaha	Big Bear	350	Unknown
QB	Yamaha	Big Bear	350	Unknown
QB	Yamaha	FZ450	450	2004
QB	Yamaha	Grizzly	Unknown	Unknown
QB	Yamaha	Kodiak	400	Unknown
QB	Yamaha	Kodiak	Unknown	Unknown
QB	Yamaha	Kodiak	400	Unknown
QB	Yamaha	Kodiak	400	2003
QB	Yamaha	Kodiak Ultramatic	Unknown	Unknown
QB	Yamaha	Kodiak YFM 400F	400	2002*
QB	Yamaha	Moto 4	225	1987

Vehicle	Make	Model (as described in the coronial files)	Size [cc]	Year
QB	Yamaha	Moto 4	250	Unknown
QB	Yamaha	Moto 4	Unknown	Unknown
QB	Yamaha	Raptor	90	Unknown
QB	Yamaha	Raptor	700	Unknown
QB	Yamaha	Timber Wolf	200	Unknown
QB	Yamaha	Ultramatic Grizzly	350	Unknown
QB	Yamaha	Unknown	Unknown	Unknown
QB	Yamaha	Unknown	350	2005
QB	Yamaha	Unknown	450	Unknown
QB	Yamaha	Unknown	250	Unknown
QB	Yamaha	Unknown	Unknown	1991*
QB	Yamaha	Unknown	350	Unknown
QB	Yamaha	Unknown	Unknown	Unknown
QB	Yamaha	Warrior 4	350	Unknown
QB	Yamaha	YFZ	350	Unknown
6x6	Polaris	Sportsman	500	2000
SxS	Kawasaki	Mule	600	Unknown
SxS	Yamaha	Rhino 700	700	Unknown

Appendix B: Range of farm work activities

- Chasing kangaroo
- Checking fences
- Checking QB mechanics
- Grounds maintenance
- Mustering – sheep, cattle
- Poisoning trees
- Rounding up sheep
- Showing visitor around property
- Spraying
- Transport - carting rocks, cattle work, check cattle, check something, checking cattle, checking mail, fence material, locate missing cow, preparing paddock, rural duties
- Watering

ATTACHMENT 2: Quad Bike-Related Fatal and Non-Fatal Injuries: Examination of Injury Patterns and Crash Circumstances by Dr. Rebecca Mitchell

Never Stand Still | Science | Transport and Road Safety (TARS) Research | School of Aviation

Quad bike related fatal and non-fatal injuries: Examination of injury patterns and crash circumstances

A TARS Research report

Dr. Rebecca Mitchell
Transport and Road Safety (TARS) Research | School of Aviation | UNSW

October 2013

TRANSPORT AND ROAD SAFETY
(TARS) RESEARCH

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Abbreviations

ABS	Australian Bureau of Statistics
ANZSIC	Australian and New Zealand Standard Industry Classification
ANZSCO	Australian and New Zealand Standard Classification of Occupations
ASCO	Australian Standard Classification of Occupations
ATV	All-terrain Vehicle
APDC	Admitted Patient Data Collection
CI	95% Confidence Interval
COPS	Computerised Operational Policing System
EDDC	Emergency Department Data Collection
EDIS	Emergency Department Information System
ICD-10	International Classification of Diseases and Related Health Problems, 10th Revision
ICD-10-AM	International Classification of Diseases, 10th Revision, Australian Modification
Km/h	Kilometres per hour
LHD	Local Health District
NCIS	National Coronial Information System
NDS	National Data Set for Compensation-based Statistics
NEC	Not Elsewhere Classified
NSW	New South Wales
PHREDSS	Public Health Real-time Emergency Department Surveillance System
RCAS	Road Crash Analysis System
ROPS	Roll Over Protective Structure
SAPHaRI	Statistical Application for Population Health and Intelligence
TARS	Transport and Road Safety Research
TOOCS	Type of Occurrence Classification Scheme
UNSW	University of New South Wales
US	United States

Executive Summary

All-terrain vehicles (ATVs), or Quad bikes, are a popular off-road vehicle that are used largely in agricultural settings for a variety of activities, such as general personal transport, checking or mustering stock or conducting spraying. Quad bikes, while a useful and versatile off-road vehicle, have been associated with both fatal and non-fatal injuries of their occupants. The injurious incidents have commonly involved the operator losing control of the vehicle and either falling from the vehicle or the vehicle rolling or flipping over, with injuries commonly occurring to the head, neck and thorax. The aim of this research is to describe the injury profile and incident circumstances for Quad bike related incidents, largely in New South Wales (NSW) Australia, by examining routinely collected data from administrative data collections regarding fatally and non-fatally injured operators and/or passengers in Quad bike related incidents.

Information on the injury patterns and causal circumstances of fatal and non-fatal Quad bike related injuries was obtained from the following data collections: Safe Work Australia's National Dataset for Compensation-based Statistics (NDS), WorkCover NSW's workers' compensation scheme claims, WorkCover NSW's incident reports, Transport for NSW's Road Crash Analysis System (RCAS), the NSW Admitted Patient Data Collection (APDC), and the NSW Public Health Real-time Emergency Department Surveillance System (PHREDSS).

The data collections examined have different inclusion criteria and were examined across different time periods. The NDS (excluding NSW and Tasmania) contained 208 claims related to Quad bike incidents during 1 July 2006 to 30 June 2011. WorkCover NSW's workers' compensation scheme contained 232 claims during 1 September 2003 to 1 July 2011 and WorkCover NSW's incident reports contained 80 incidents during 1 September 2003 to 3 November 2012 for Quad bike incidents. The RCAS identified 12 Quad bike related fatalities during 1 January 2006 to 16 October 2012. There were 1,515 special all-terrain related vehicles identified in the NSW APDC during 1 July 2000 to 30 June 2011 and there were 3,300 Quad bikes, 40 small non-adult Quad bikes, and 11 side by side vehicles identified in the PHREDSS during 1 January 2006 to 31 December 2012.

A number of administrative data collections were examined to provide a snapshot of the information currently available to identify the number and describe type of Quad bike crash and the nature of injuries experienced. While information was readily available to describe the demographic characteristics of injured individuals, the information contained within the data collections was not ideal to describe the model of Quad bike and any attachments, the purpose for which the Quad bike was being used and circumstances of the crash, including geographic typology. An in-depth prospective study of Quad bike crashes is needed in Australia to obtain detailed information regarding the circumstances of Quad bike crashes.

1. Introduction

Quad bikes, are four wheeled vehicles that have a single seat that is straddled by the operator, use low pressure tyres, and are steered using handle bars. They have varying engine sizes (49 to 1,000cc) and are capable of speeds up to 120km/h [1]. These vehicles are designed for use on off-road terrain and are commonly used for work and increasingly for recreational purposes.

Quad bikes are commonly used in the agricultural industry for a variety of activities, including general personal transport, checking stock, mustering, and to facilitate spraying, seeding and fertilizing [2, 3]. Quad bikes are also used in other industries in work related capacities, such as land management, emergency medical response, search and rescue, beach safety and management, and law enforcement and security [3].

In Australia, it is estimated that there were approximately 270,000 Quad bikes in use in 2010 [4]. This compares to an estimated 80,000 Quad bikes in use in New Zealand agriculture in 2010 [5] and an estimated 10 million Quad bikes in use by 16 million individuals in 2008 in the United States (US) [3].

In the last five years, there have been a number of population-based epidemiological reports published that have reported on the number, incidence and nature of circumstances of fatal and non-fatal injuries associated with Quad bike use in the US [3, 6-9], Canada [10] and Australia [11-13]. These incidents have commonly involved the operator losing control of the vehicle and either falling from the vehicle or the vehicle rolling or flipping over, with injuries commonly occurring to the head, neck and thorax. Various injury risk factors have been identified that are associated with Quad bike incidents, these include young age, male operators, inexperience, lack of helmet use, and greater Quad bike engine size [6, 9, 14].

This research aims to describe the injury profile and incident circumstances for Quad bike related incidents, largely in New South Wales (NSW) Australia, by examining routinely collected data from administrative data collections regarding fatally and non-fatally injured operators and/or passengers in Quad bike related incidents.

2. Method

This section describes the data collections used to obtain information on the injury patterns and contributing factors to fatal and non-fatal Quad bike related injuries. These data collections included: Safe Work Australia's National Dataset for Compensation-based Statistics (NDS), WorkCover NSW's workers' compensation scheme claims, WorkCover NSW's incident reports, Transport for NSW's Road Crash Analysis System (RCAS), the NSW Admitted Patient Data Collection (APDC), and the NSW Public Health Real-time Emergency Department Surveillance System (PHREDSS).

It is important to note that it was not possible to determine from the data whether some vehicles described as ATVs or Quad bikes were actually Side by Side Vehicles (SSVs). Thus some vehicles denoted as ATVs or Quad bikes may have actually been SSVs. The issue of improving data quality is discussed later in the report.

Ethics approval for this project was obtained from the University of New South Wales (UNSW) Human Research Ethics Advisory Panel H (Approval number: 08/2012/62), and the NSW Population and Health Services Research Ethics Committee (Approval number: 2013/09/476).

2.1 Australian data collections

2.1.1 Safe Work Australia National Dataset for Compensation-based statistics

The NDS is compiled each year by Safe Work Australia from workers' compensation claims made under state, territory and Australian Government worker's compensation Acts. The NDS does not include all work related injury, only the injury of employees who are covered by workers' compensation (i.e. it does not generally include self-employed workers or contractors). Data in the NDS are classified using the Type of Occurrence Classification Scheme (TOOCS) [15, 16]. The 3rd edition of the TOOCS has been progressively introduced in each Australian jurisdiction from 2006-07 [15]. The TOOCS agency code for ATV/ Quad bikes was introduced in TOOCS version 3. Previously, in TOOCS version 2 [16], ATV/ Quad bikes were included in the agency code for motorcycles and sidecars, scooters and trail bikes and were not able to be specifically identified using the agent of injury classification.

The severity of the injury is defined differently in the jurisdictions, but was segregated into fatalities, permanent injuries (i.e. the worker is considered totally and permanently incapacitated for any type of work e.g. brain damage resulting in total paralysis OR complete or partial loss of or loss of the use of any part of the body faculty, as a result of which, although able to work, the earning capacity of the worker or opportunities for employment are permanently affected e.g. amputation) or temporary injuries (i.e. worker has been injured, but will be able to resume normal duties at a later date). Occupation was classified using the Australian Standard Classification of Occupations (ASCO) [17] and Industry was classified using the Australian and New Zealand Standard Industry Classification (ANZSIC) [18].

Data were extracted from 1 July 2006 to 30 June 2011 from the NDS where the agent of injury was identified as an ATV/ Quad bike (TOOCS agent: 2929). Data were only available from Australian jurisdictions who provided workers' compensation claims data that had been classified using TOOCS version 3 to the NDS. Data were available from Comcare (i.e. Australian government employees) from 1 July 2009 to 30 June 2011, Queensland from 1 July 2006 to 30 June 2011, South Australia from 1 July 2010 to 30 June 2011, Victoria from 1 July 2009 to 30 June 2011 and Western Australia from 1 July 2010 to 30 June 2011. No data were available from New South Wales (NSW) or Tasmania from the NDS on Quad bikes for this report.

2.1.2 WorkCover NSW Workers' Compensation Scheme Claims Data

WorkCover NSW's workers' compensation scheme claims data includes information on work related deaths, injury and disease (excluding dust diseases) claims of workers employed in NSW. Information recorded in the workers' compensation claims data includes: details of the claim, incident and employer; the claim activity; the claimant's time lost from work;

services provided to the claimant; and the actual and estimated compensation payments and recoveries relating to the claim.

Information in the NSW workers' compensation claims data were classified using the TOOCS v2 or TOOCS v3 [15, 16]. Occupation was classified using the Australian and New Zealand Standard Classification of Occupations (ANZSCO) [19] and Industry was classified using the Australian and New Zealand Standard Industry Classification (ANZSIC) [18].

Data were obtained from the WorkCover NSW workers' compensation scheme claims data collection for records where: (i) the claim was entered onto the Agent's system on or between 1 September 2003 and 1 July 2011 and (ii) the agent of injury or the breakdown agent of injury was identified as an ATV/ Quad bike (TOOCS agent: 2929) OR the incident description included any of the words: 'ATV', 'all terrain vehicle', 'quad', 'quad bike', 'farm quad', 'farm utility vehicle', 'farm utv', 'farm utility cart', 'buggy', or '4 wheeler'. A total of n=424 records were identified by WorkCover NSW and provided to the study investigators.

Each of the text descriptions were reviewed by one of the investigators (RM) and n=192 (45.3%) records were removed as not involving a Quad bike related incident. The records that were removed largely involved incidents with golf buggies, moon buggies, landscaping or transport buggies. There were two injuries where the worker was operating an Quad bike that were not related to the Quad bike operation, which were both excluded. One incident involved the worker dismounting the Quad bike and then being kicked by a horse and the second incident involved a worker who was riding an Quad bike who was bitten by a snake. There were n=232 workers' compensation claim records relating to Quad bike incidents that were analysed. Data provided by WorkCover NSW was up-to-date at the time that it was extracted, however this data is subject to change due to the progression of data and the application of regular data quality reviews.

2.1.3 WorkCover NSW Incident Data

Incidents can be notified directly to WorkCover NSW or via a workers' compensation claim. For some incident notifications no physical inspection was undertaken. When an incident is notified to WorkCover NSW a determination is made based on the available information whether the issue requires some action by WorkCover. In investigating an incident WorkCover NSW may determine that there may be no actual visit/inspection needed for their purposes.

Information recorded include the date of the incident, demographics of the injured, and a description of the incident. If an investigation has been undertaken, an investigation report will also be available. The text descriptions may allow the extraction of the following information: the type of Quad bike, whether the activity was for work or recreation, the ground surface, whether the injury involved the operator or passenger, whether a roll over protective structure (ROPS), restraints or helmets were present or worn, whether there was a front or rear load or any attachments, and injury outcome.

Data were obtained from the WorkCover NSW incident data for records where: (i) the date of the incident was on or between 1 September 2003 and 3 November 2012 and (ii) the narrative included any of the words: 'ATV', 'all terrain veh', 'all terrain veh', 'quad', 'quad bike', 'quadbike' or 'quad-bike'. [1]

There were n=80 incident records relating to Quad bikes provided. Data provided by WorkCover NSW was up-to-date at the time that it was extracted, however this data is subject to change due to the progression of data and the application of regular data quality reviews.

2.1.4 Transport for NSW Road Crash Analysis System

All road crashes attended by, or reported to, police are entered on the NSW Police Computerised Operational Policing System (COPS) database by the reporting officer. Information from COPS is then sent to Transport to NSW where it is electronically loaded into the RCAS. The RCAS, therefore, contains information on every road traffic crash reported to police across NSW including information regarding the individual as well as information about the circumstances of the crash. Transport for NSW then identifies crashes that meet the national guidelines for the reporting and classifying of road vehicle crashes [20] and this information is retained within Transport for NSW's CrashLink database.

As Quad bike crashes occur mostly off the surveyed road reserve in NSW (i.e. not on a public roadway), these crashes are generally not included within the CrashLink database. An electronic search of the RCAS for any fatal crashes involving a Quad bike during 1 January 2009 to 15 October 2012 was performed by Transport for NSW staff.

2.1.5 NSW Admitted Patient Data Collection

Data from the APDC include information on inpatient separations for individuals from public and private hospitals, private day procedures, and public psychiatric hospitals. The APDC contains information on patient demographics, source of referral, diagnoses, external cause(s), separation mode and clinical procedures. Each health record relates to individual episodes of care in hospital, which end with the discharge, transfer, or death of the patient, or when the service category for the admitted patient changes. Diagnoses and external cause codes are classified using the International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM) [21]. Data were obtained from the APDC from 1 July 2000 to 30 June 2011.

All-terrain vehicle related hospitalised injuries were identified if there was a principal external cause code present that indicated 'occupant of special all-terrain or other motor vehicle designed primarily for off-road use, injured in transport accident' (i.e. ICD-10-AM range: V86.0 to V86.9)[1]. Using the 'V86' external cause classification, there were n=2,219 hospitalisation records identified as involving a special all-terrain vehicle. From 2003-04, the number of wheels on the special all-terrain vehicle could be indicated. Of the 2,219 records,

[1] It is noted that Quad bikes would typically not have a ROPS structure and restraints. However, they may have an Operator Protection Device such as a Quadbar. It was not possible to determine from the data whether some vehicles described as ATVs or Quad bikes were actually Side by Side Vehicles (SSVs). Thus some vehicles denoted as ATVs or Quad bikes may have actually been SSVs.

n=222 (10.0%) were indicated to be 'two-wheeled special all-terrain or other off-road motor vehicles' and n=390 (17.6%) were indicated to be 'three-wheeled special all-terrain or other off-road motor vehicles' and these hospitalisations were excluded from the analysis. Of the 1,607 remaining hospitalisations, n=92 (5.7%) were not indicated to involve a principal diagnosis of an injury (i.e. ICD-10-AM range S00-T98) and were also excluded from the analysis.

Work related all-terrain vehicle related hospitalised injuries were identified using activity classifications that indicated the injured person was working at the time of the injury (i.e. ICD-10-AM: Y93.2 or U73.0 to U73.09); and/or a payment status was equal to '40: compensable - NSW workers' compensation'; and/or supplementary factors related to causes of morbidity and mortality was equal to 'work related condition' (i.e. ICD-10-AM: Y96). Hospitalisations that met any of the above criteria were considered to be work related hospitalisations.

Hospitalised injuries experienced while riding 2-wheel motorcycles in off-road conditions were identified if there was a principal external cause code that indicated 'motorcycle rider injured in transport accident' (i.e. ICD-10-AM range: V20 to V29); if the incident involved 'a non-traffic incident' (i.e. ICD-10-AM fourth character of: 0 or 1 or 2, indicating the incident occurred off-road); and if there was a principal diagnosis of an injury (i.e. ICD-10-AM range S00-T98) (See Appendix 1 for results).

2.1.6 NSW Public Health Real-time Emergency Department Surveillance System

Information was obtained from PHREDSS for the period from 1 January 2006 to 31 December 2012. Data collection for PHREDSS began on 1 September 2003 at 12 EDs in public hospitals in the Sydney metropolitan region. From 2006 there were 38 EDs providing data to PHREDSS and in 2012 there were 59 EDs providing data to PHREDSS. Twenty-four EDs consistently provided data to PHREDSS over the whole seven year period. Hospitals in Sydney, South Western Sydney and Western Sydney Local Health District (LHDs) changed their ED information system in either 2007 or 2008 and it was not possible to collect data from these hospitals for an extended period of time.

Development and preparation of data from PHREDSS is described in detail elsewhere [22] and an overview is provided here. The majority of public hospital EDs in NSW collect information on patient presentations using the Emergency Department Information System (EDIS), a patient administration and clinical data collection system [22]. Information from EDIS is then conveyed by LHD to the NSW Ministry of Health via computer networks. Data is collected in PHREDSS by either real-time electronic messaging or through data extraction every 4 to 6 hours and batch file transfer from LHDs.

Data items recorded in PHREDSS include: patient age, gender, postcode of residence, arrival date and time, triage category, visit type (e.g. emergency, planned, or unplanned return visit), mode of arrival (e.g. ambulance, private vehicle), country of birth, provisional diagnoses, hospital code, departure status (e.g. discharged, admitted to hospital, transferred, or died), free-text presenting problem (e.g. lacerated finger), and free-text triage nurse assessment. The provisional diagnosis is allocated by ED clinical staff via keyword searching and selection of the most relevant diagnosis.

An initial free-text search of the free-text nurse triage assessment and free-text presenting problem fields was conducted by the NSW Ministry of Health using the following key words: 'QUAD' and 'BIKE' or 'QUAD' and 'BIKING' or 'ATV' or 'ALL TERRAIN' or 'ALL-TERRAIN'. There were 3,721 records that contain the keywords that were provided to the investigators at TARS Research.

True case identification was assessed by one of the investigators (RM) who reviewed each narrative to determine if the presentation was Quad bike related or not. For an ED presentation to be considered as a 'true' Quad bike related presentation, the presentation was required to have been identified as Quad bike related during the keyword search and to have a corresponding Quad bike related narrative in the free-text nurse triage assessment or free-text presenting problem fields. Alternatively, 'false positive' cases were identified as an Quad bike related presentation using the keyword search, but the free-text nurse triage assessment or free-text presenting problem fields were not Quad bike related.

The proportion of 'true' Quad bike related injury presentations was calculated by dividing the number of ED presentations identified as Quad bike related by the keyword search alone by the number of Quad bike related ED presentations that were identified as Quad bike related by the keyword search in the free-text nurse triage assessment or free-text presenting problem fields.

Quad bike rollovers were identified from the narrative text using a conservative approach. Quad bike rollovers were only identified if the narrative text specified that the Quad bike 'rolled', 'flipped', 'tipped over', 'overturned' or that the patient fell off and then the Quad bike fell on the patient, the patient was trapped under the Quad bike, the Quad bike was on top of the patient, or the patient was subjected to 'crush forces' beneath the Quad bike. Side by side vehicles were not specifically identified in narrative text, however, if the narrative text indicated that the vehicle had a roll cage, rollbar, 5-point harness, or seat belt, these vehicles were identified as potential side by side vehicles. From the narrative text, some Quad bikes were identified as 'toy quad bikes', '50cc Quad bikes', 'kid's quads', 'mini quad' or 'electric quads'. All of these vehicles were termed 'small non-adult Quad bikes'.

Information on the provisional injury diagnosis was identified using keyword searching of the provisional diagnosis description using the keywords of 'fracture', 'laceration', 'open wound', 'contusion', 'dislocation', 'superficial', and 'head'.

2.3 Data management and analysis

Descriptive analyses were performed using SAS version 9.3 [23]. Both the workers' compensation claims data and the incident reports provided by WorkCover NSW contained short narrative descriptions of the incidents. The specific mechanism of the Quad bike related incident was classified from these incident narrative descriptions. The body location and nature of injury was classified using TOOCS v2 and TOOCS v3 in the workers' compensation claims data provided by WorkCover NSW and reclassification was conducted to TOOCS v3.

Within the APDC, hospitalisations relating to transfers between hospitals and changes in the service category (e.g. a change from acute to rehabilitation for a patient during one episode of care in a single facility) were excluded in order to attempt to partly eliminate 'multiple counts'.

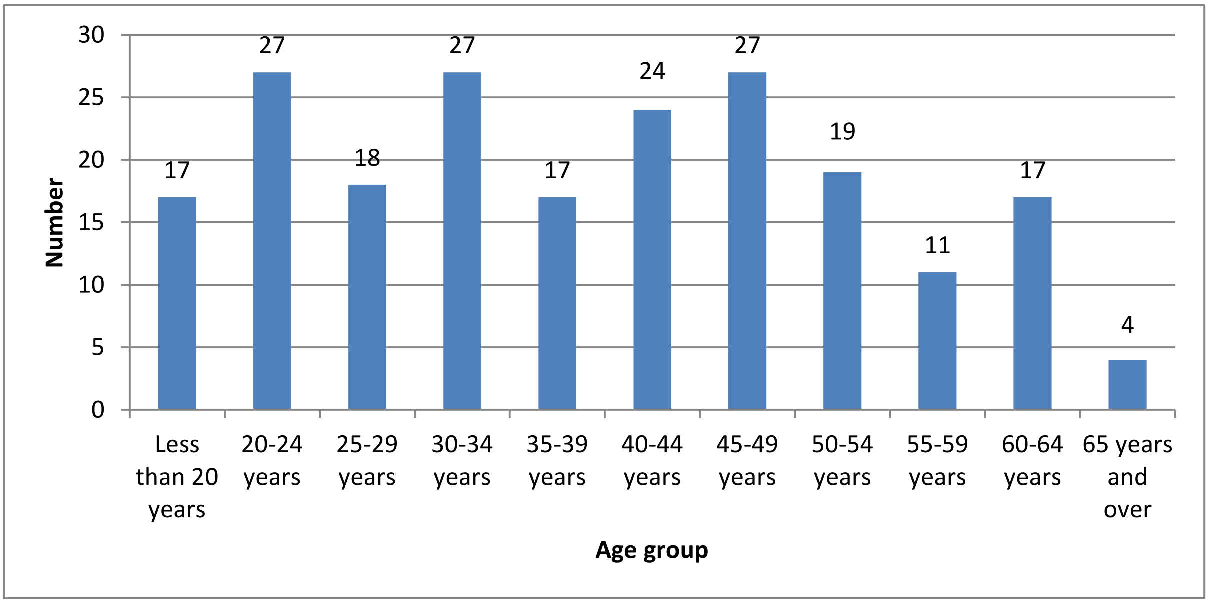
3. Results

The results are reported in six sections. Section 3.1 describes the profile Quad bike related workers' compensation claims from the Australian NDS, Section 3.2 describes Quad bike related worker's compensation claims in the NSW workers' compensation claims data and Section 3.3 describes Quad bike related injury identified in WorkCover NSW incident reports. Section 3.4 describes the Quad bike incidents reported in the RCAS in NSW, Section 3.5 describes all-terrain related injury hospital admissions in NSW, and Section 3.6 describes the Quad bike related injuries identified in the PHDRESS in NSW.

3.1 Quad bike related injury in the Australian National Dataset for Compensation-based Statistics

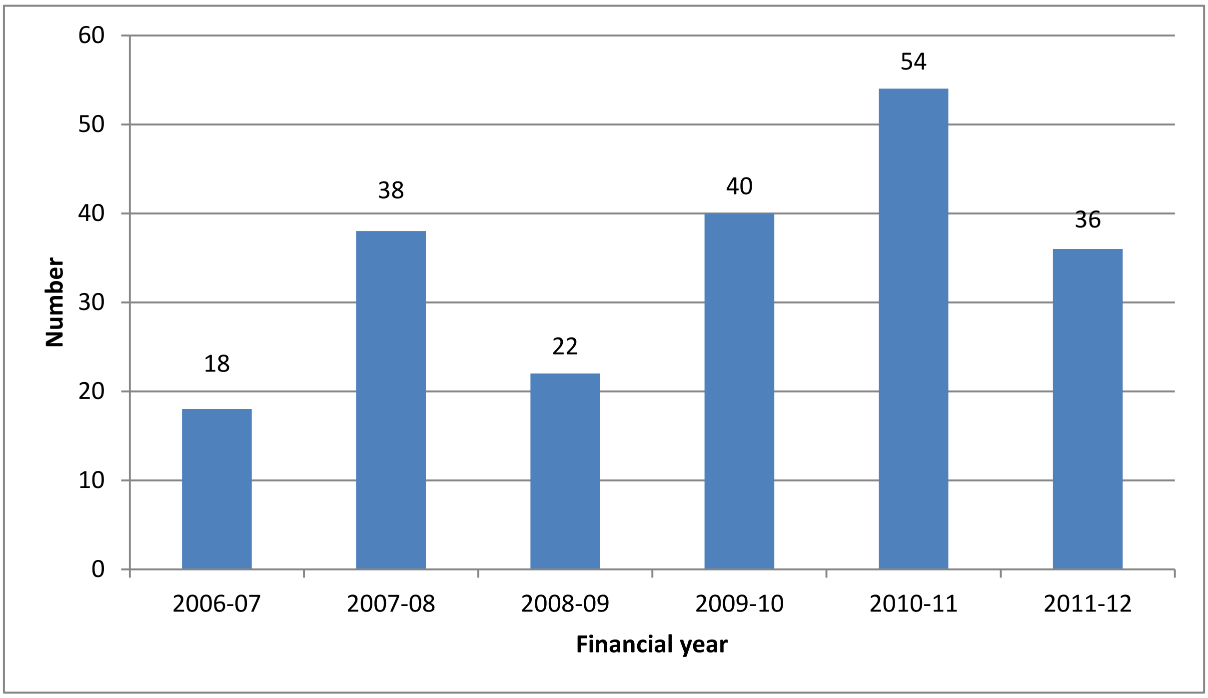
There were 208 Quad bike related workers' compensation claims identified in the NDS during 1 July 2006 to 30 June 2011. Of these, the majority (86.1%, n=179) resulted in temporary injuries for the worker, 27 (13.0%) resulted in permanent injuries, and two incidents resulted in a fatality (1.0%). The majority of Quad bike related incidents involved males (84.6%, n=176), with 32 (15.4%) incidents involving females. The mean age of the injured worker was 38.7 years (range: 16-69 years). Just over two-thirds (67.3%) of incidents involved workers aged between 20 and 49 years (Figure 2-3.1).

Figure 2-3.1: Number of Quad bike related incidents by age group, NDS 2006-07 to 2010-11



There were 153 (73.6%) Quad bike incidents identified in Queensland, 31 (14.9%) in Victoria, 17 (8.2%) in South Australia, five (2.4%) involving Australian Government employees, and two (1.0%) incidents were identified in Western Australia. The number of Quad bike related incidents identified in the NDS varied by year, with 54 (26.0%) incidents identified in 2010-11 (Figure 2-3.2).

Figure 2-3.2: Number of Quad bike related incidents by financial year, NDS 2006-07 to 2010-11



Agriculture, forestry and fishing (54.8%), government administration and defence (13.0%) and transport and storage (6.3%) accounted for three-quarters of the industries where a worker was injured in an incident involving an Quad bike. Beef cattle farming (25.5%) accounted for one-quarter of all worker injuries involving an Quad bike (Table 2-3.1).

Table 2-3.1: Number and percent of Quad bike related incidents by industry, NDS 2006-07 to 2010-11

Industry	n	%
Agriculture, forestry and fishing	**114**	**54.8**
Vegetable growing	*7*	*3.4*
Grape growing	*4*	*1.9*
Fruit growing nec[1]	*17*	*8.2*
Grain-sheep and grain-beef cattle farming	*5*	*2.4*
Sheep-beef cattle farming	*6*	*2.9*
Beef cattle farming	*53*	*25.5*
Dairy cattle farming	*7*	*3.4*
Manufacturing	**3**	**1.4**
Construction	**7**	**3.4**
Wholesale trade	**4**	**1.9**
Retail trade	**8**	**3.9**
Accommodation, cafes and restaurants	**1**	**0.5**
Transport and storage	**13**	**6.3**
Road freight transport	*4*	*1.9*
Communication services	**1**	**0.5**
Property and business services	**7**	**3.4**
Government administration and defence	**27**	**13.0**
State government administration	*13*	*6.3*
Local government administration	*13*	*6.3*
Education	**2**	**1.0**
Health and community services	**4**	**1.9**
Cultural and recreational services	**6**	**2.9**
Personal and other services	**11**	**5.3**
Total	**208**	**100.0**

[1]nec: not elsewhere classified.

Labourers and related workers (32.7%) and tradespersons and related workers (26.9%) accounted for approximately two-thirds of all occupational groups who were injured in an incident involving an Quad bike. Farm overseers (21.2%) and farm hands (18.3%) were the two most commonly represented occupations that sustained and Quad bike related injury (Table 2-3.2).

Table 2-3.2: Number and percent of Quad bike related incidents by occupation, NDS 2006-07 to 2010-11

Occupation	n	%
Managers and administrators	**17**	**8.2**
Professionals	**8**	**3.9**
Associate professionals	**14**	**6.7**
Tradespersons and related workers	**56**	**26.9**
Farm overseers	*44*	*21.2*
Intermediate clerical, sales and service workers	**8**	**3.9**
Intermediate production and transport workers	**34**	**16.4**
Other mobile plant operators	*15*	*7.2*
Truck drivers	*7*	*3.4*
Elementary clerical, sales and service workers	**3**	**1.4**
Labourers and related workers	**68**	**32.7**
Farm hands	*37*	*18.3*
Other agricultural and horticultural labourers	*4*	*1.9*
Other miscellaneous labourers and related workers	*22*	*10.6*
Total	**208**	**100.0**

Vehicle accidents accounted for two-thirds (66.4%) of all injury mechanisms that involved Quad bikes. Muscular stress (11.6%) and falls (7.3%) were also common injury mechanisms for incidents involving Quad bikes (Table 2-3.3).

Table 2-3.3: Number and percent of Quad bike related incidents by injury mechanism, NDS 2006-07 to 2010-11

Injury mechanism	n	%
Falls from a height	7	3.4
Falls on the same level	8	3.9
Stepping kneeling or sitting on objects	1	0.5
Hitting stationary objects	6	2.9
Being hit by falling objects	2	1.0
Being trapped by moving machinery or equipment	1	0.5
Being trapped between stationary and moving objects	2	1.0
Exposure to mechanical vibration	2	1.0
Being hit by moving objects	4	1.9
Long term exposure to sounds	1	0.5
Muscular stress while lifting carrying or pulling down objects	2	1.0
Muscular stress while handling objects other than lifting carrying or putting down	22	10.6
Muscular stress with no objects being handled	4	1.9
Repetitive movement low muscle loading	2	1.0
`Contact with hot objects	1	0.5
Exposure to a traumatic event	1	0.5
Vehicle accident	138	66.4
Other and multiple mechanisms	2	1.0
Unspecified mechanisms of injury	2	1.0
Total	208	100.0

The trunk area (29.3%), upper limbs (27.4%) and lower limbs (25.0%) were the most common body regions of injury. Injuries to the shoulder (13.0%), lower back (12.5%) and knee (10.6%) were the most common body locations of the injury (Table 2-3.4).

Table 2-3.4: Number and percent of Quad bike related incidents by body location of injury, NDS 2006-07 to 2010-11

Body location of injury	n	%
Head	**15**	**7.2**
Neck	**6**	**2.9**
Trunk	**61**	**29.3**
Lower back	*26*	*12.5*
Ribs	*8*	*3.9*
Upper limbs	**57**	**27.4**
Shoulder	*27*	*13.0*
Wrist	*11*	*5.3*
Lower limbs	**52**	**25.0**
Knee	*22*	*10.6*
Lower leg	*7*	*3.4*
Ankle	*10*	*4.8*
Multiple locations	**13**	**6.3**
Non-physical locations	**1**	**0.5**
Unspecified locations	**3**	**1.4**
Total	**208**	**100.0**

Sprains and strains of joints and adjacent muscles (35.6%) and fractures (29.8%) accounted for almost two-thirds of all nature of injuries (Table 2-3.5). Fractures were most common in the shoulder (19.4%) and wrist (16.1%), with sprains and strains most common in the lower back (18.9%) or knee (18.9%). All dorsopathies occurred in the lower back (Table 2-3.6).

Table 2-3.5: Number and percent of Quad bike related incidents by nature of injury, NDS 2006-07 to 2010-11

Nature of injury	n	%
Fractures	62	29.8
Fracture of vertebral column with or without mention of spinal cord lesion	5	2.4
Dislocation	5	2.4
Sprains and strains of joints and adjacent muscles	74	35.6
Intracranial injury, including concussion	4	1.9
Internal injury of chest, abdomen and pelvis	3	1.4
Open wound not involving traumatic amputation	6	2.9
Superficial injury	1	0.5
Contusion with intact skin surface and crushing injury, excluding those with fracture	13	6.3
Foreign body on external eye, in ear or nose or in respiratory, digestive or reproductive systems	1	0.5
Multiple injuries	5	2.4
Other and unspecified injuries	4	1.9
Deafness	1	0.5
Arthropathies and related disorders - disorders of the joints	1	0.5
Dorsopathies - disorders of the spinal vertebrae and intervertebral discs	11	5.3
Disorders of muscle, tendons and other soft tissues	7	3.4
Other diseases of skin and subcutaneous tissue	1	0.5
Hernia	1	0.5
Other diseases of the respiratory system	2	1.0
Mental disorders	1	0.5
Total	**208**	**100.0**

Table 2-3.6: Number and percent of Quad bike related incidents by the most common body location and nature of injury, NDS 2006-07 to 2010-11

Body location	Nature of injury										
	Fracture		Fracture of vertebral column with or without mention of spinal cord lesion		Sprains and strains of joints & adjacent muscles		Dorsopathies		Other injury[1]		Total
	n	%	n	%	n	%	n	%	n	%	
Lower back	-	-	-	-	-	-	11	100.0	1	1.8	26
Back unspecified	-	-	4	80.0	3	4.1	-	-	-	-	7
Ribs	7	11.3	-	-	-	-	-	-	1	1.8	8
Shoulder	12	19.4	-	-	8	10.8	-	-	7	12.5	27
Wrist	10	16.1	-	-	1	1.4	-	-	-	-	11
Knee	2	3.2	-	-	14	18.9	-	-	6	10.7	22
Other location[2]	31	50.0	1	20.0	34	45.9	-	-	41	73.2	107
Total	**62**	**100.0**	**5**	**100.0**	**74**	**100.0**	**11**	**100.0**	**56**	**100.0**	**208**

[1] Other includes: dislocation; intracranial injury (including concussion); internal injury of chest, abdomen and pelvis; open wound not involving traumatic amputation; superficial injury; contusion; foreign body; multiple injuries; deafness; arthropathies; disorders of muscle, tendons and other soft tissues; other disease of skin and subcutaneous tissue; hernia; other disease of the respiratory system; mental disorders; other and unspecified injuries.

[2] Other includes: head; neck; chest; other upper and lower limb areas; other and unspecified multiple injuries.

The median and total time lost in hours varied by year, with lower lost time hours in both 2008-09 and 2009-10 then the preceding or following financial years. The median cost of workers' compensation for claims reported to the NDS ranged from $2,709 to $7,292 per year. Overall, there were 89,851 lost time hours following a worker sustaining an injury following Quad bike use at a cost of AUD$5.3 million (Table 2-3.7).

Table 2-3.7: Median and total lost time and workers' compensation payment following Quad bike related incidents by financial year, NDS 2006-07 to 2010-11

Financial year	Lost time (hrs)		Payment ($AUD)	
	Median	Total	Median	Total
2006-07	269.5	10,413.5	7,296	816,402
2007-08	270.5	20,462.5	6,558	1,792,674
2008-09	57.5	4,196.0	3,403	360,269
2009-10	61.9	12,434.2	2,709	901,188
2010-11	167.5	24,320.3	4,726	918,623
2011-12	151.0	18,024.4	5,828	530,531
Total		**89,850.9**		**5,319,687**

3.2 Quad bike related injury in NSW workers' compensation claims data

There were 232 Quad bike related workers' compensation claims identified during 1 September 2003 to 1 July 2011. Of these, three-quarters of Quad bike related incidents involved males (75.4%, n=175), with 57 (24.6%) incidents involving females. The mean age of the injured worker was 37.5 years (range: 17-74 years). Just over two-thirds (67.7%) of incidents involved workers aged between 20 and 49 years (Figure 2-3.3). The majority of incidents involved the worker sustaining a temporary disability (86.6%, n=201), 12.1% (n=28) of workers experienced a permanent partial disability, and 3 (1.3%) workers died. The number of Quad bike related incidents identified in the NSW workers' compensation claims varied by year, with an average of 27 Quad bike related claims per year between 2004 and 2010 (Figure 2-3.4).

Figure 2-3.3: Number of Quad bike related incidents by age group, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

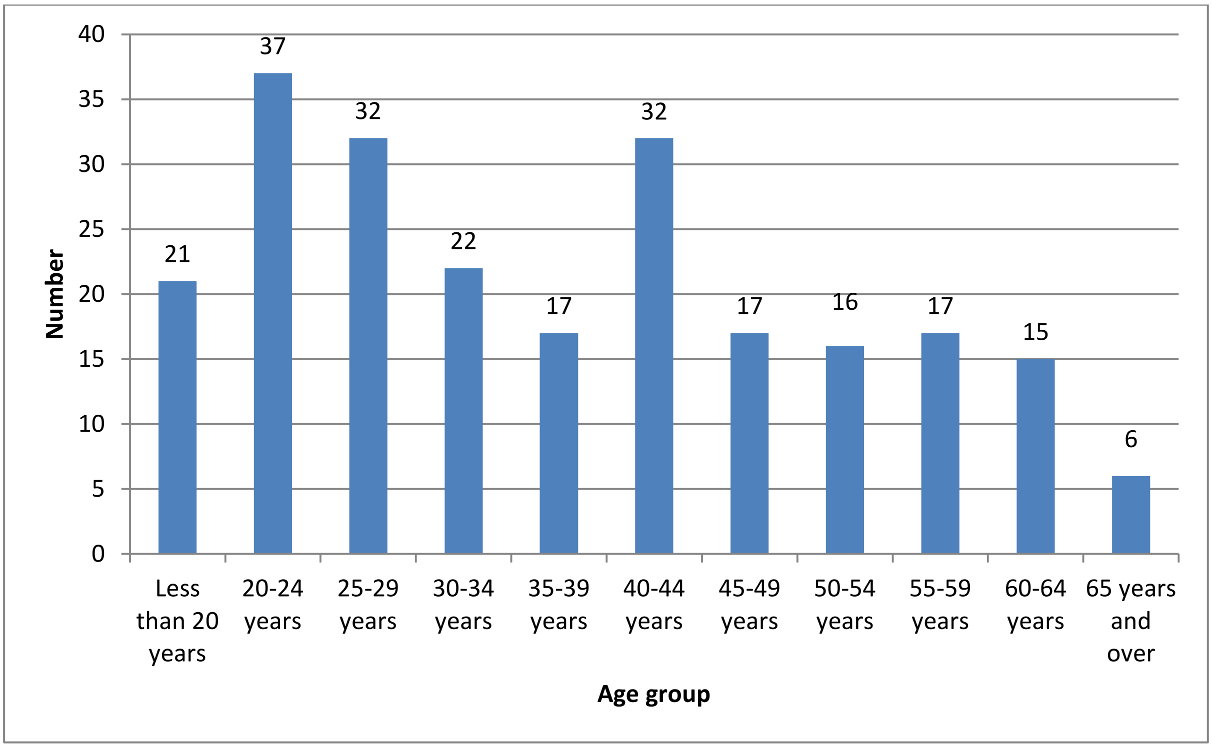
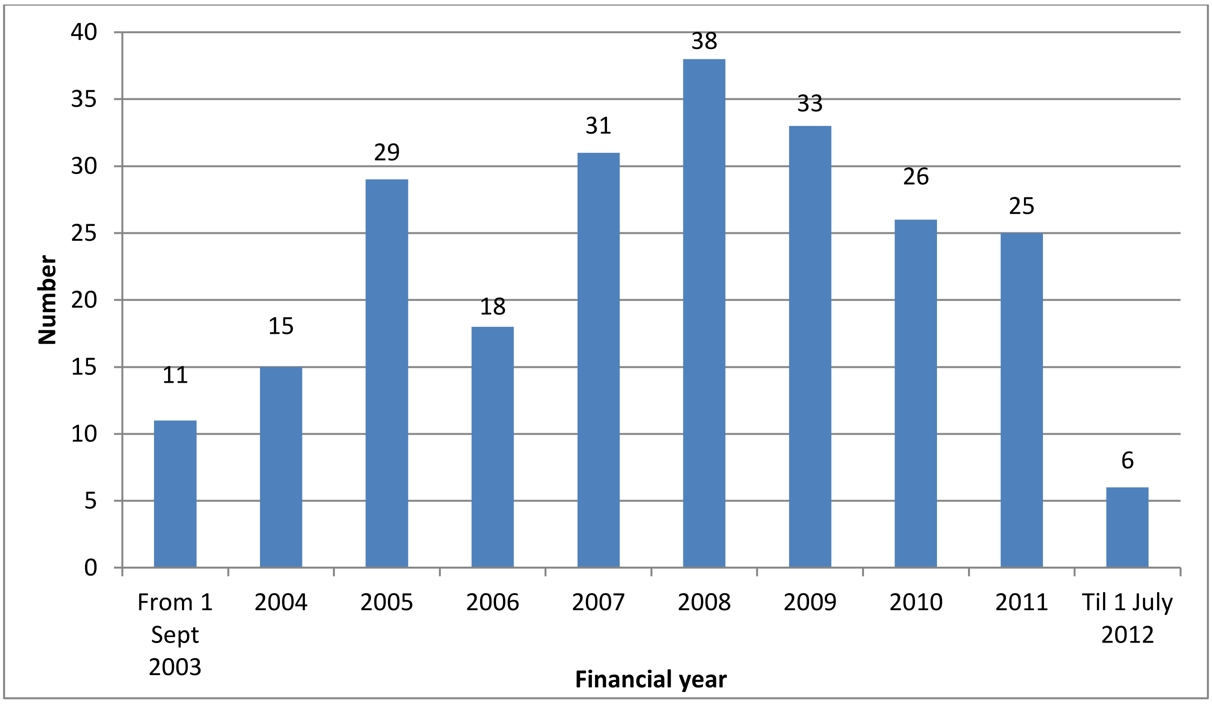


Figure 2-3.4: Number of Quad bike related incidents by year, NSW workers' compensation claims, 1 Sept 2003-1 July 2011



Agriculture, forestry and fishing (63.4%), property and business services (6.0%), cultural and recreational services (4.7%) and government administration and defence (4.3%) accounted for over three-quarters of the industries where an worker was injured in an incident involving an Quad bike. Specialised beef cattle farming (15.5%) and horse farming (10.8%) accounted for almost one-third of all worker injuries involving an Quad bike (Table 2-3.8).

Table 2-3.8: Number and percent of Quad bike related incidents by industry, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Industry	n	%
Agriculture, forestry and fishing	**147**	**63.4**
Beef cattle farming (specialised)	*36*	*15.5*
Sheep-beef cattle farming	*12*	*5.2*
Grain-sheep or grain-beef cattle farming	*20*	*8.6*
Cotton growing	*10*	*4.3*
Dairy cattle farming	*14*	*6.0*
Horse farming	*25*	*10.8*
Mining	**5**	**2.2**
Manufacturing	**8**	**3.4**
Construction	**6**	**2.6**
Wholesale trade	**4**	**1.7**
Retail trade	**5**	**2.2**
Accommodation, cafes and restaurants	**3**	**1.3**
Transport and storage	**3**	**1.3**
Property and business services	**14**	**6.0**
Government administration and defence	**10**	**4.3**
Education	**1**	**0.4**
Health and community services	**7**	**3.0**
Cultural and recreational services	**11**	**4.7**
Personal and other services	**3**	**1.3**
Total	**232**	**100.0**

Labourers (54.3%) and managers (15.5%) accounted for over two-thirds of all occupational groups who were injured in an incident involving an Quad bike. Crop farmer workers (20.3%), livestock farm workers (14.2%), livestock farmers (6.9%) and mixed crop and livestock farm workers (6.5%) were the four most common occupations that sustained and Quad bike related injury (Table 2-3.9).

Table 2-3.9: Number and percent of Quad bike related incidents by occupation, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Occupation	n	%
Managers	**36**	**15.5**
Livestock farmers	*16*	*6.9*
Mixed crop and livestock farmers	*8*	*3.5*
Professionals	**14**	**6.0**
Technicians and trades workers	**24**	**10.3**
Gardeners	*7*	*3.0*
Community and personal service workers	**15**	**6.5**
Clerical and administrative workers	**6**	**2.6**
Sales workers	**6**	**2.6**
Machinery operators and drivers	**5**	**2.2**
Labourers	**126**	**54.3**
Crop farm workers	*47*	*20.3*
Livestock farm workers	*33*	*14.2*
Mixed crop and livestock farm workers	*15*	*6.5*
Other farm, forestry and garden workers	*6*	*2.6*
Other miscellaneous labourers	*6*	*2.6*
Total	**232**	**100.0**

Vehicle accidents accounted for two in every five Quad bike related incidents (41.0%). Muscular stress (13.8%) and falls (16.4%) were also common injury mechanisms for incidents involving Quad bikes (Table 2-3.10).

Table 2-3.10: Number and percent of Quad bike related incidents by injury mechanism, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Injury mechanism	n	%
Falls from a height	20	8.6
Falls on the same level	18	7.7
Stepping kneeling or sitting on objects	4	1.7
Hitting stationary objects	15	6.5
Hitting moving objects	4	1.7
Being hit by falling objects	6	2.6
Being hit by an animal	1	0.4
Being trapped by moving machinery or equipment	2	0.9
Being trapped between stationary and moving objects	4	1.7
Exposure to mechanical vibration	1	0.4
Being hit by moving objects	20	8.6
Muscular stress while lifting carrying or pulling down objects	11	4.7
Muscular stress while handling objects other than lifting carrying or putting down	15	6.5
Muscular stress with no objects being handled	6	2.6
Single contact with chemical or substance	2	0.9
Vehicle accident	95	41.0
Rollover[1]	3	1.3
Other and multiple mechanisms	2	0.9
Unspecified mechanisms of injury	3	1.3
Total	**232**	**100.0**

[1] Note: Rollover was introduced as a classification in 2011.

Upper limbs (27.2%), the trunk area (24.1%) and lower limbs (19.4%) were the most common body regions of injury. Injuries to the shoulder (10.8%), lower back (9.5%), ribs (5.2%) and knee (5.2%) were the most common body locations of the injury (Table 2-3.11).

Table 2-3.11: Number and percent of Quad bike related incidents by body location of injury, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Body location of injury	n	%
Head	**19**	**8.2**
Neck	**9**	**3.9**
Trunk	**56**	**24.1**
Lower back	*22*	*9.5*
Ribs	*12*	*5.2*
Upper limbs	**63**	**27.2**
Shoulder	*25*	*10.8*
Wrist	*14*	*6.0*
Lower limbs	**45**	**19.4**
Knee	*12*	*5.2*
Lower leg	*8*	*3.5*
Ankle	*19*	*8.2*
Multiple locations	**34**	**14.7**
Other and multiple systemic conditions	**1**	**0.4**
Unspecified locations	**5**	**2.2**
Total	**232**	**100.0**

Sprains and strains of joints and adjacent muscles (41.8%) and fractures (22.4%) accounted for almost two-thirds of all nature of injuries (Table 2-3.12). Fractures were most common in the ribs (19.2%) and wrist (17.3%), with sprains and strains most common in the lower back (18.6%), shoulder (15.5%) or ankle (12.4%). Contusions commonly occurred to the knee (12.0%) (Table 2-3.13).

Table 2-3.12: Number and percent of Quad bike related incidents by nature of injury, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Nature of injury	n	%
Fractures	52	22.4
Fracture of vertebral column with or without mention of spinal cord lesion	4	1.7
Dislocation	2	0.9
Sprains and strains of joints and adjacent muscles	97	41.8
Intracranial injury, including concussion	3	1.3
Internal injury of chest, abdomen and pelvis	2	0.9
Open wound not involving traumatic amputation	12	5.2
Superficial injury	9	3.9
Contusion with intact skin surface and crushing injury, excluding those with fracture	25	10.8
Foreign body on external eye, in ear or nose or in respiratory, digestive or reproductive systems	2	0.9
Burns	1	0.4
Poisoning and toxic effects of substances	1	0.4
Multiple injuries	5	2.2
Other and unspecified injuries	13	5.6
Disorders of muscle, tendons and other soft tissues	3	1.3
Hernia	1	0.4
Total	**232**	**100.0**

Table 2-3.13: Number and percent of Quad bike related incidents by the most common body location and nature of injury, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Body location	Nature of injury								
	Fracture		Sprains and strains of joints & adjacent muscles		Contusion with intact skin surface and crushing injury		Other injury[1]		Total
	n	%	n	%	n	%	n	%	
Lower back	-	-	18	18.6	1	4.0	3	5.2	22
Back unspecified	-	-	4	4.1	1	4.0	-	-	5
Ribs	10	19.2	1	1.0	1	4.0	-	-	12
Shoulder	6	11.5	15	15.5	1	4.0	3	5.2	25
Wrist	9	17.3	5	5.2	-	-	-	-	14
Knee	-	-	4	4.1	3	12.0	5	8.6	12
Lower leg	7	13.5	1	1.0	-	-	-	-	8
Ankle	5	9.6	12	12.4	1	4.0	1	1.7	19
Other location[2]	15	28.8	37	38.1	17	68.0	46	79.3	115
Total	**52**	**100.0**	**97**	**100.0**	**25**	**100.0**	**58**	**100.0**	**232**

[1] Other includes: fracture of vertebral column with or without mention of spinal cord lesion, dislocation; intracranial injury (including concussion); internal injury of chest, abdomen and pelvis; superficial injury; foreign body; multiple injuries; burns; poisoning; disorders of muscle, tendons and other soft tissues; hernia; other and unspecified injuries.

[2] Other includes: head; neck; chest; other upper and lower limb areas; other and unspecified multiple injuries.

Examples of a few short text descriptions available in the workers' compensation data for Quad bike incidents are shown below:

Was looking after live stock on the farm and was riding a quad bike, hit a ditch and fell off the bike and landed on the left shoulder.

Fell off quad bike whilst riding around property.

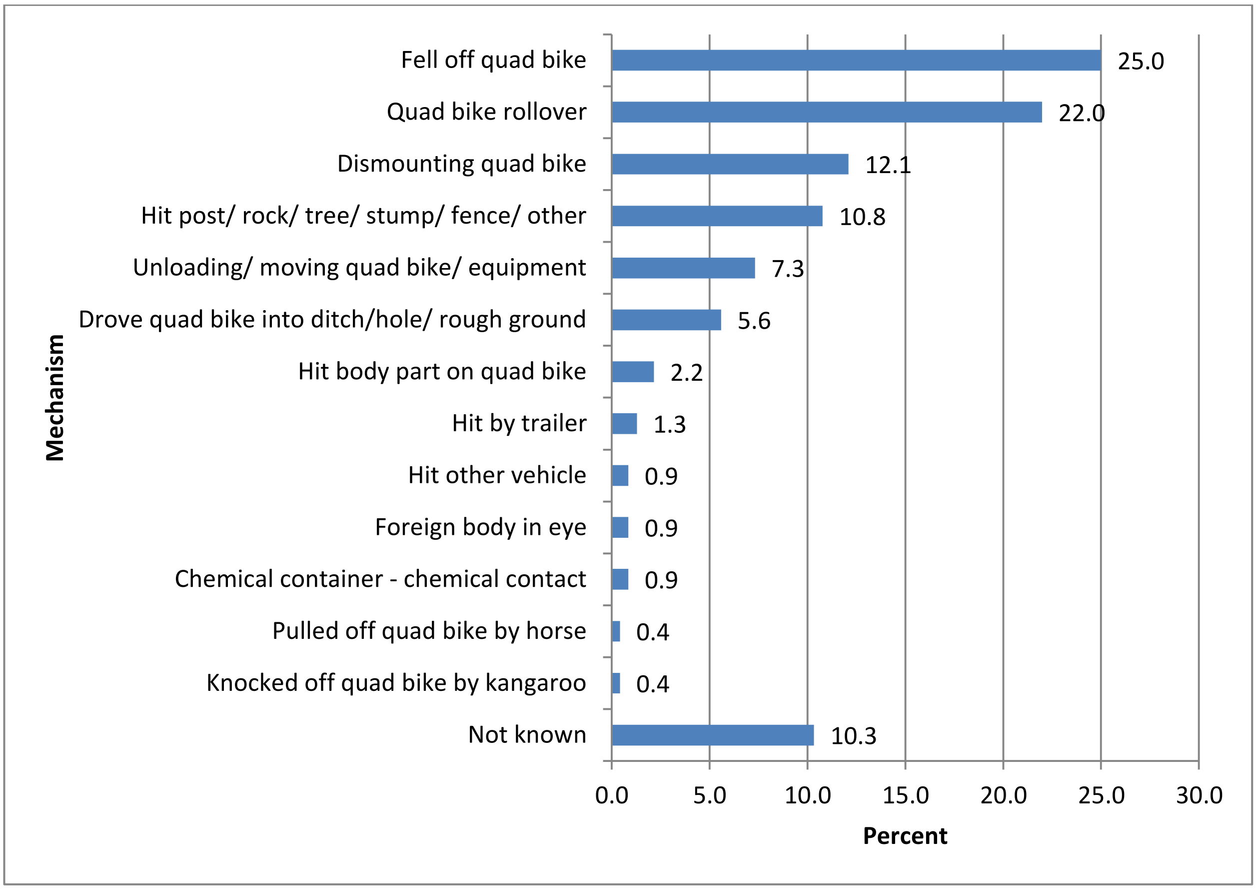
Riding quad bike and went through a gully and the front right wheel of bike entered a wash out, bike rolled over.

Quad bike rolled while weed spraying.

Worker was riding 4 Wheeler and hit a stump in the long grass, fell from bike hurting shoulders and neck.

All of the short text descriptions of the incident circumstances were further classified, where possible, to examine the type of Quad bike related incident. One-quarter of the incidents involved the worker falling off the Quad bike (n=58), 22% involved a Quad bike rollover (n=51), 12.1% occurred while dismounting the Quad bike, and 10.8% involved the worker hitting a post, rock, tree, stump, fence or other object (n=25) while riding the Quad bike (Figure 2-3.5).

Figure 2-3.5: Percent of Quad bike related incidents by mechanism, NSW workers' compensation claims, 1 Sept 2003-1 July 2011 (n=232)



Of the 51 incidents where the Quad bike was reported to have rolled over, the most common nature of injuries were fractures (37.3%), sprains and strains (25.5%) and contusions (17.6%). Fractures were most common in the ribs (31.6%) and sprains and strains were most common in the shoulder (23.1%) (Table 2-3.14).

Table 2-3.14: Number of Quad bike related incidents that involved the Quad bike flipping over by the most common body location and nature of injury, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

	Fractures	Sprains and strains	Contusion with intact skin surface and crushing injury	Superficial injury	Multiple injuries	Fracture of vertebral column	Dislocation	Internal injury of chest, abdomen and pelvis	Open wound	Other and unspecified injuries	Total
Head											
Eye - unspecified	0	0	0	0	0	0	0	0	1	0	**1**
Nose	1	0	0	0	0	0	0	0	0	0	**1**
Neck											
Neck bones, muscles and tendons	0	1	0	0	0	0	0	0	0	0	**1**
Trunk											
Upper back	0	1	0	0	0	0	0	0	0	0	**1**
Lower back	0	2	1	1	0	0	0	0	0	0	**4**
Back - other and multiple	0	0	0	0	0	1	0	0	0	0	**1**
Back - unspecified	0	0	1	0	0	0	0	0	0	0	**1**
Ribs	6	0	1	0	0	0	0	0	0	0	**7**
Breast	0	0	1	0	0	0	0	0	0	0	**1**
Pelvic bones, muscles and tendons	1	0	0	0	0	0	0	0	0	0	**1**
Upper limbs											
Shoulder	1	3	0	0	0	0	1	0	0	1	**6**
Upper arm	1	0	0	0	0	0	0	0	0	0	**1**
Wrist	2	0	0	0	0	0	0	0	0	0	**2**
Fingers	1	0	0	0	0	0	0	0	0	0	**1**
Thumb	0	0	1	0	0	0	0	0	0	0	**1**
Lower limbs											
Upper leg	0	0	1	0	0	0	0	0	0	0	**1**
Knee	0	0	1	0	0	0	0	0	0	0	**1**
Lower leg	2	0	0	0	0	0	0	0	0	0	**2**
Lower limb - unspecified locations	1	1	0	0	0	0	0	0	0	0	**2**
Ankle	2	1	0	0	0	0	0	0	0	0	**3**
Multiple locations											
Trunk and limbs	0	2	0	0	0	0	0	0	0	0	**2**
Trunk - multiple locations	0	1	0	0	0	0	0	0	0	0	**1**
Abdomen - other and multiple	0	0	0	0	0	0	0	1	0	0	**1**
Upper limb - multiple locations	0	0	1	0	0	0	0	0	0	0	**1**
Other specified multiple locations	1	1	1	2	2	0	0	0	0	0	**7**
Total	**19**	**13**	**9**	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**51**

During the period 2004 to 2011, the median cost of workers' compensation for claims in NSW ranged from $900 to $8,523 per year. Overall, there was a cost of AUD$5,439,777 for workers who sustained an injury following an incident involving an Quad bike in NSW (Table 2-3.15).

Table 2-3.15: Median and total workers' compensation payment following Quad bike related incidents by financial year, NSW workers' compensation claims, 1 Sept 2003-1 July 2011

Calendar year	**Payment ($AUD)**	
	Median	Total
2003[1]	930	319,239
2004	900	77,586
2005	1,688	426,433
2006	3,089	334,521
2007	5,103	1,182,977
2008	2,125	1,674,006
2009	8,523	881,657
2010	2,062	284,492
2011	3,365	206,648
2012[2]	2,462	52,217
Total		**5,439,777**

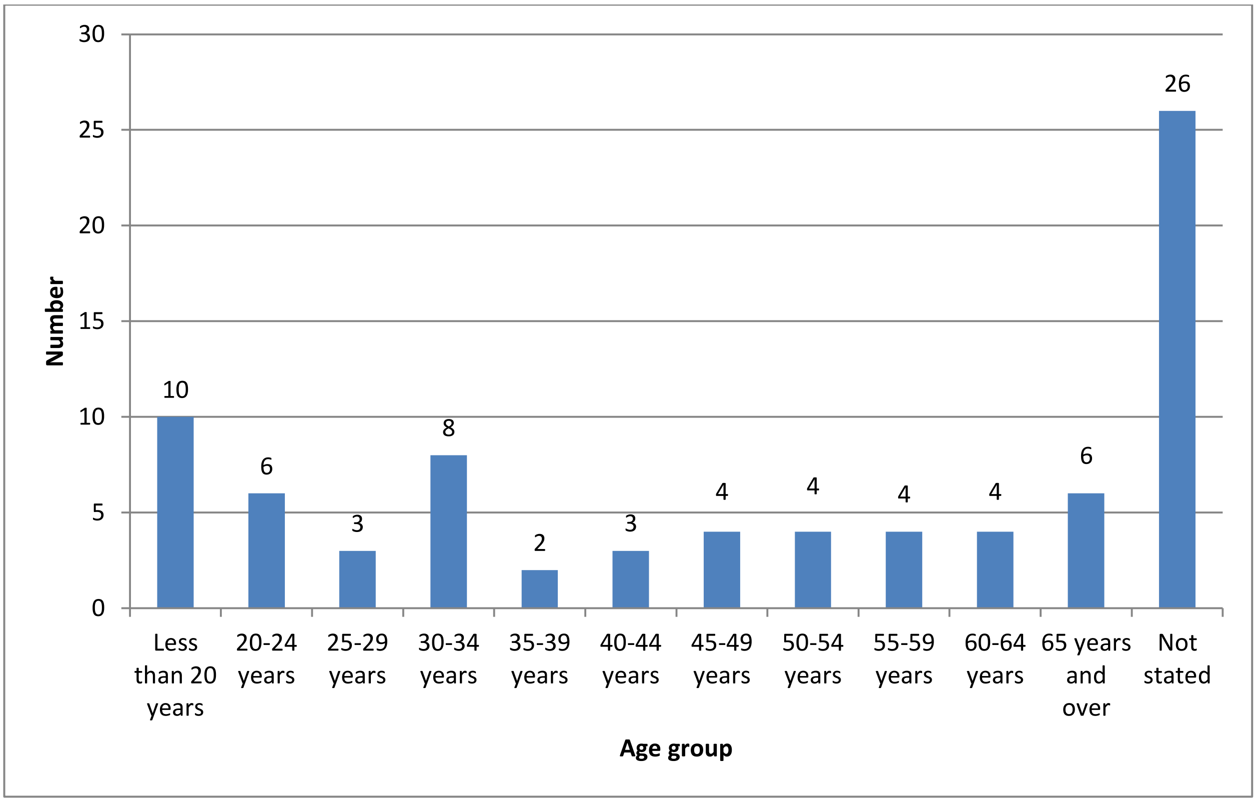
[1] Includes 1 September 2003 to 31 December 2003 only.

[2] Includes 1 January 2012 to 30 June 2012 only.

3.3 Quad bike related injury in WorkCover NSW incident reports

There were 80 Quad bike related incidents identified from incident reports where the date of the incident was on or between 1 September 2003 and 3 November 2012. Of these 80 Quad bike related incidents, 77.5% (n=62) involved males and 17 (21.3%) incidents involved females, with gender not recorded for one incident. Where the age of the injured individual was reported (n=54), the mean age was 40.1 years (range: 9 to 87 years) and just less than one-quarter of incidents (23.8%) involved an individual aged 29 years or less, with 10 (18.5%) individuals aged less than 20 years (Figure 2-3.6).

Figure 2-3.6: Number of Quad bike related incidents by age group, NSW incident data, 1 Sept 2003-3 November 2012



Working (85.0%, n=68) was the activity most commonly performed at the time of the incident. Other activities included recreation (7.5%, n=6) and training (1.3%, n=1), with the activity performed unknown for five (6.3%) incidents. Of the 80 incidents, 17 (21.3%) involved an individual who was fatally injured.

Some information on the model of Quad bike was recorded in 29 (36.3%) incident reports. However, this information was often general in nature (e.g. Honda, Yamaha, Polaris), with no specific Quad bike model frequently identified. Whether the Quad bike was fitted with a crush or rollover protective structure (ROPS) was usually not known (92.5%).[1] Where ROPS use was specified, there were three (3.8%) Quad bikes fitted with a ROPS and three (3.8%) not fitted with a ROPS. Whether the Quad bike was fitted with or carrying a load/attachment was generally not known (87.5%, n=70). However, where a type of load/attachment was indicated, there were four (5.0%) 100 litre spray tanks, one (1.3%) 70 litre spray tank, two (2.5%) spray tanks with volume unknown, and one (1.3%) trailer attached to the Quad bike. In two instances (2.5%), there was no load indicated to be carried by the Quad bike.

Restraint use was not known in all incident reports, bar one (1.3%), where a restraint was indicated to have been worn, this is likely an SSV as Quad bikes do not have restraints. Helmet use was not generally known (52.5%, n=42), but in 19 (23.8%) incidents a helmet was worn and in 19 (23.8%) incidents a helmet was not worn.

Examples of a few short text descriptions available in the incident data relating to Quad bikes are shown below:

> *Quad bike struck a concealed rock and over balanced, rolled and the deceased person was pinned to the ground.*

> *Passenger was sitting on quad bike leading a calf, deceased person was standing on the sideboard operating the quad bike. Calf has bucked and knocked the deceased person over the handlebars causing deceased person to strike head on gravel road.*

> *Driving a quad bike up a hill when it flipped over backwards onto the injured person.*

> *Crossing irrigation ditch on quad bike. While climbing the slope quad bike lost power momentarily and the front wheels lifted off the ground and as power came back on the quad bike rolled over backwards on top of the injured person.*

All of the short text descriptions of the incident circumstances were further classified, where possible, to examine the type of Quad bike incident. Forty percent (n=32) of incidents involved a Quad bike rollover, 23.8% (n=19) involved the individual hitting a post, rock, tree, stump, fence or other object and 13.8% (n=11) involved the individual falling off the Quad bike (Figure 2-3.7).

Figure 2-3.7: Percent of Quad bike related incidents by mechanism, NSW incident data, 1 Sept 2003-3 November 2012 (n=80)

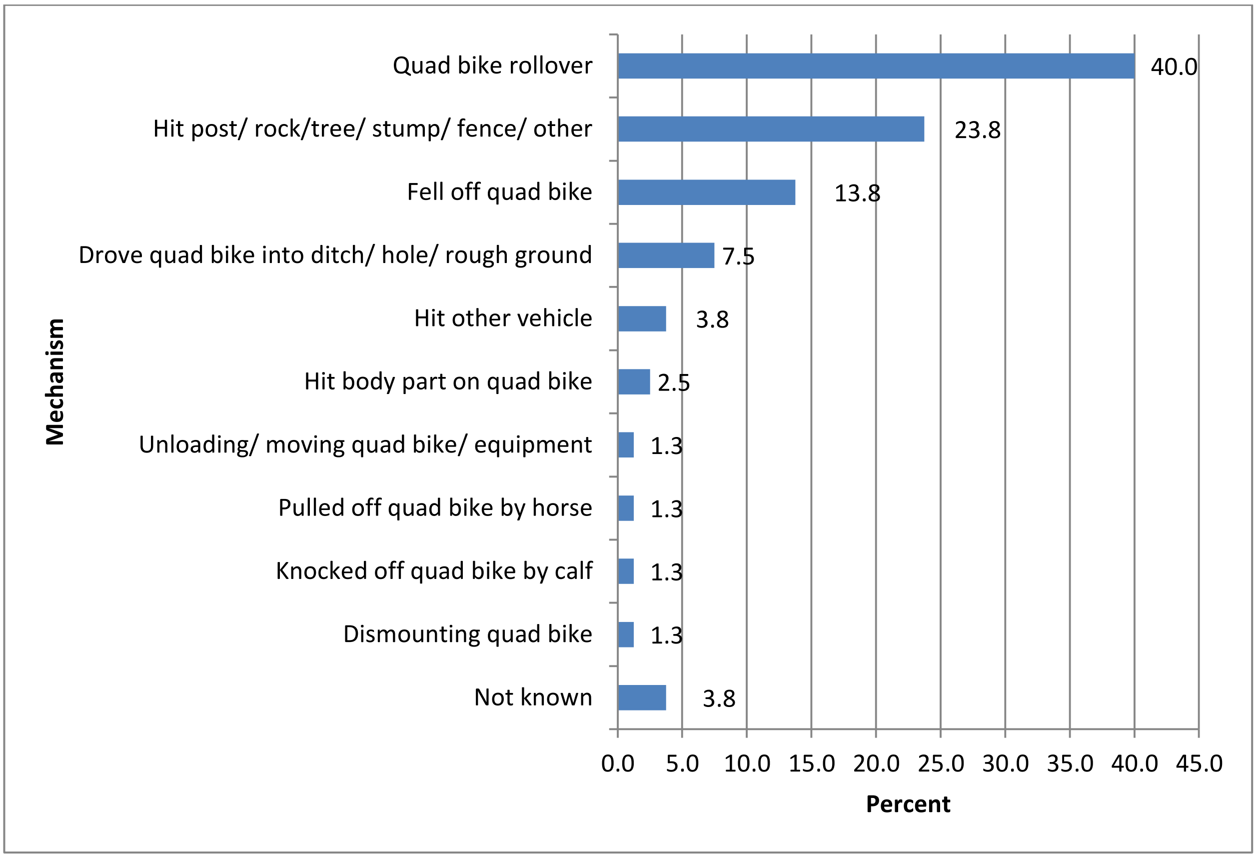


Table 2-3.16 describes the characteristics of the incident, the injuries received and the ground surface for the 32 incidents where the Quad bike flipped over. Fracture of the pelvis was a common injury identified in the incident data and a ground surface that was slopped was the most common type of ground surface in these incidents.

Table 2-3.16: Incident description, injuries and ground surface of Quad bike related incidents that involved the Quad bike flipping over, NSW incident data, 1 Sept 2003-3 November 2012 (n=32)

Incident description[1]	Injuries	Ground surface
Traversing a slope, dog ran in front, braked heavily, turning at the time which caused the bike to tilt and rollover. Worker has jumped clear and not been injured.	None	Slope in paddock
Quad "tipped over" while student riding round the track.	Back strain/bruising	Track – even dirt surface
While getting back on quad that was left idling in reverse, has knocked the accelerator causing the bike to move sharply in reverse causing the injured person to knock the accelerator lever onto full throttle. Quad rolled onto side.	Bruising to upper body	Flat ground
While manoeuvring out of the ravine, the quad rolled onto operator.	Crush injuries to head & neck*	Creek
Chasing sheep, "gunned it" up a slope and bike flipped	Fractured L1 vertebrae	Slope in paddock
Driving a quad bike up a hill when it flipped over backwards onto the injured person.	Fractured L3 vertebrae	Embankment
As the injured person was traversing a 40 degree embankment the quad bike has rolled backwards.	Fractured T12 vertebrae	Embankment
Quad bike became entangled in old fencing wire hidden by the grass causing the quad bike to stop suddenly and dislodging the injured person, quad bike landed on the injured person.	Fractured collarbone, bruising to the chest & stomach	Paddock
Travelling up slope away from the river, bike overturned and fell on top of injured person.	Fractured pelvis, arm, leg, & collapsed lungs	Riverbank
Reversing in steep country and the quad bike rolled back on top of the injured person.	Fractured pelvis, dislocated hip	Creek embankment
Injured person was riding up a river bank when the quad bike tipped over striking the injured person.	Fractured pelvis, cracked socket, perforated bladder	Riverbank

Incident description[1]	**Injuries**	**Ground surface**
Quad has lost control, left hand side rear tyre has come of the rim, injured person has over-corrected and the quad has rolled over. Injured person was not wearing restraint.	Fractured pelvis & torn knee ligament	Forest road, wet & slippery
Wheel may have wobbled and the bike rolled while turning a corner onto the injured person causing injury.	Fractured right side of face & left hand	Gravel road
Crossing irrigation ditch on quad bike. While climbing the slope, quad bike lost power momentarily and the front wheels lifted off the ground and as power came back on the quad bike rolled over backwards on top of the injured person.	Fractured leg & lacerations & bruising to ankle	Irrigation ditch
Attempting to slow quad resulted in locked brakes and quad sliding towards a pole. Quad rolled over while injured person was trying to avoid the pole.	Fractured left wrist, strained right wrist, multiple abrasions	Driveway
Failed to negotiate sharp bend in the road resulting in the quad tipping over on to its side.	Fractured 2 ribs & punctured lung	Graded road
Rode across a check bank, quad rolled onto side.	Fractured wrist & finger, lacerated inner thigh	Check bank
Found trapped under quad bike in river.	Heart attack due to drowning*	River embankment
Unclear. Deceased person found underneath quad bike. While unconscious, inhaled large amounts of agrochemical poison.	Inhaled poison + injuries from overturned quad*	Steep terrain
While manoeuvring out of the gully the quad rolled.	Injury to leg	Gully
Riding an quad up the side of a storage embankment. The embankment was 7 meters in height and had a gradient of approx 60 degrees. Soil at top of slope was loose. Quad lost traction at the top of the slope and flipped backwards and rolled over several times down the hill. Person's injuries sustained by the quad striking the person as it descended down the embankment.	Lacerated left arm & bruising to chest	Steep slope
The bike had travelled over an adjacent embankment at an	Neck injuries*	Embankment

Incident description[1]	**Injuries**	**Ground surface**
unknown speed. The bike became airborne ejecting the three passengers all of which were uninjured. It was suspected the bike continued and landed on its front tyres & tipped the bike & the deceased over the handlebars. It is suspected the bike landed on the deceased resulting in fatal neck injuries.		
Unclear. Deceased person found trapped under quad bike.	Possible spinal cord injury, head injury, lacerated liver*	Slight hill
Negotiating a contour bank, unknowingly drove into a wash away front-on and the quad bike flipped landing on the injured person.	Ruptured spleen	Contour bank in paddock
Quad bike suddenly lost power then surged ahead causing injured person to fall off quad bike. The bike then apparently rolled onto the injured person.	Spinal/disc injury	Unknown
Riding a quad bike which has flipped back and landed upon the injured person's head.	Injuries of 7 individuals were unknown * (n=5 were fatal)	Gully (n=1) Overgrown paddock (n=1) Hill (n=2) Unknown (n=3)
Unknown. Deceased person found trapped beneath overturned quad.		
Unclear. Deceased person found in a gully underneath quad bike.		
Found in gully with quad bike on top of injured person.		
Quad bike flipped.		
Found pinned under the quad bike.		
Riding quad bike when it overturned and rolled on top of the injured person.		

[1] Note: some identifying characteristics of individuals have been removed.
* Fatal injury.

3.4 Quad bike related fatalities in the Road Crash Analysis System in NSW

There were 12 Quad bike related fatalities that were able to be identified in the RCAS during 1 January 2009 to 15 October 2012. Forty-two percent of the Quad bike related fatalities occurred in 2011. The time of the incident varied, as did the age of the deceased. Almost all (91.7%) of the deceased were identified as the driver of the Quad bike. In seven (58.3%) of the fatal incidents, the Quad bike was identified as either rolling or overturning (Table 2-3.17).

Table 2-3.17: Quad bike related fatal incidents, Road Crash Analysis System, 1 January 2009-15 October 2012 (n=12)

Year[1]	Time of crash (24 hr)	Age of deceased	Road user type	Description
2009	15:45	11	Passenger	Quad bike fell to ground.
2009	9:00	55	Driver	Quad bike slid in to dam.
2009	9:15	81	Driver	Quad bike rolled.
2010	21:30	42	Driver	Quad bike hit tree and rolled.
2010	13:20	39	Driver	Quad bike hit tree.
2011	18:50	83	Driver	Quad bike rolled.
2011	14:30	11	Driver	Quad bike rolled.
2011	10:00	65	Driver	Quad bike rolled.
2011	10:30	66	Driver	Quad bike overturned.
2011	16:30	56	Driver	Tree branch fell on Quad bike on private property.
2012	16:55	9	Driver	Quad bike overturned.
2012	12:00	13	Driver	Driver ejected from Quad bike.

[1]Data from 2012 is incomplete, provisional and subject to change. There was one additional Quad bike rollover fatality in 2012 at the time that the data was provided, but there was no further information was available and this crash was not included in Table 2-3.17.

3.5 Special all-terrain vehicle related injury hospital admissions in NSW

There were 1,515 special all-terrain vehicle related injury hospitalisations identified during 1 July 2000 to 30 June 2011 in the APDC. Of these, over three-quarters of special all-terrain vehicle related incidents involved males (78.2%, n=1,184) and 329 (21.7%) incidents involving females, with the gender of two individuals not specified. The mean age of the injured individual was 33.1 years (range: 1-96 years). Just over one-third (34.3%) of hospitalisations involved individuals aged less than 20 years (Figure 2-3.8). Of those aged less than 20 years, 198 (13.1%) were aged 15-19 years, 182 (12.0%) were aged 10-14 years, 113 (7.5%) were aged 5-9 years, and 27 (1.8%) were aged less than 4 years.

The number of special all-terrain vehicle related incidents identified in the APDC varied by year, with an average of 138 hospitalisations per year (Figure 2-3.9). Median length of stay in hospital was one day (range: 1 to 77 days). The majority of individuals who were hospitalised were either discharged (78.6%, n=1,190) or transferred to another facility (21.1%, n=320). Four (0.3%) individuals were indicated to have died with no information on hospital separation status for one (0.1%) individual.

Figure 2-3.8: Number of special all-terrain vehicle related injury hospitalisations by age group, NSW APDC, 2000-01 to 2010-11

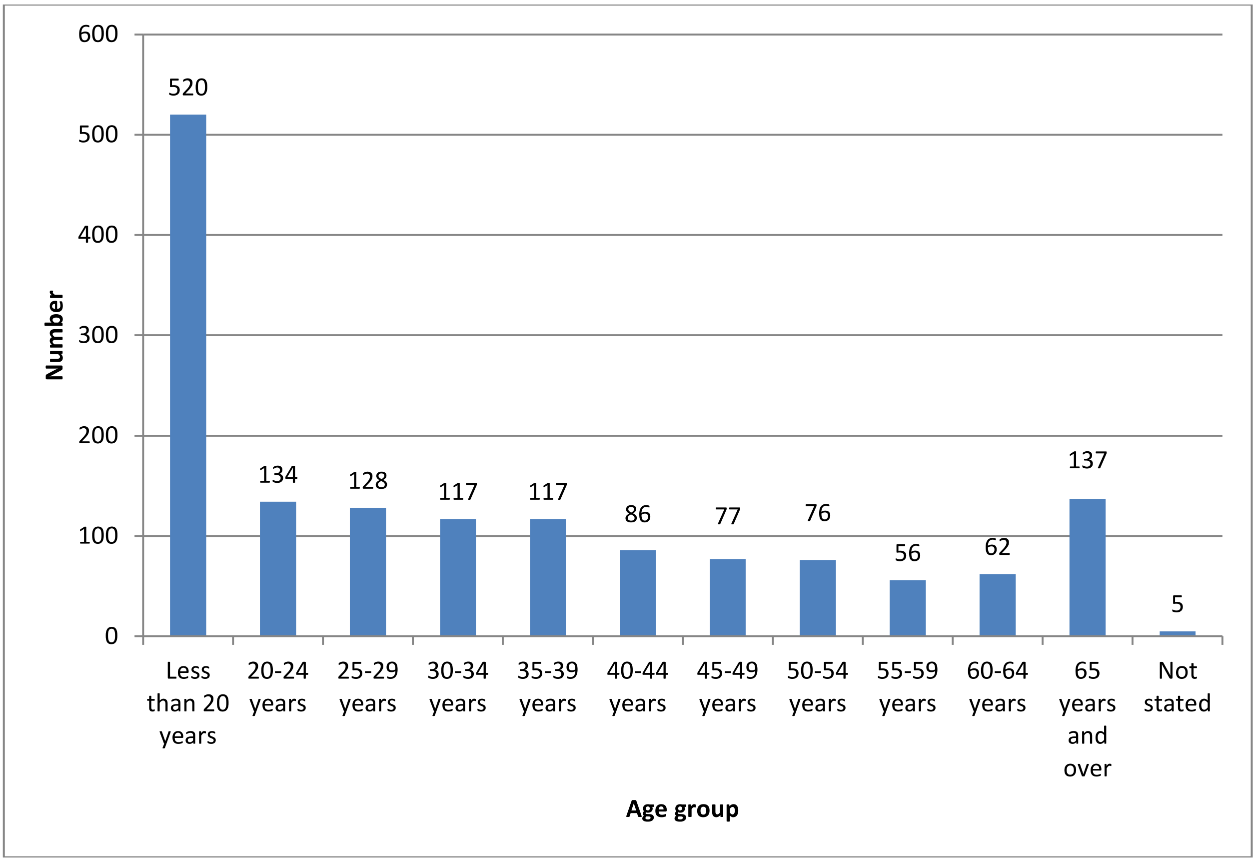
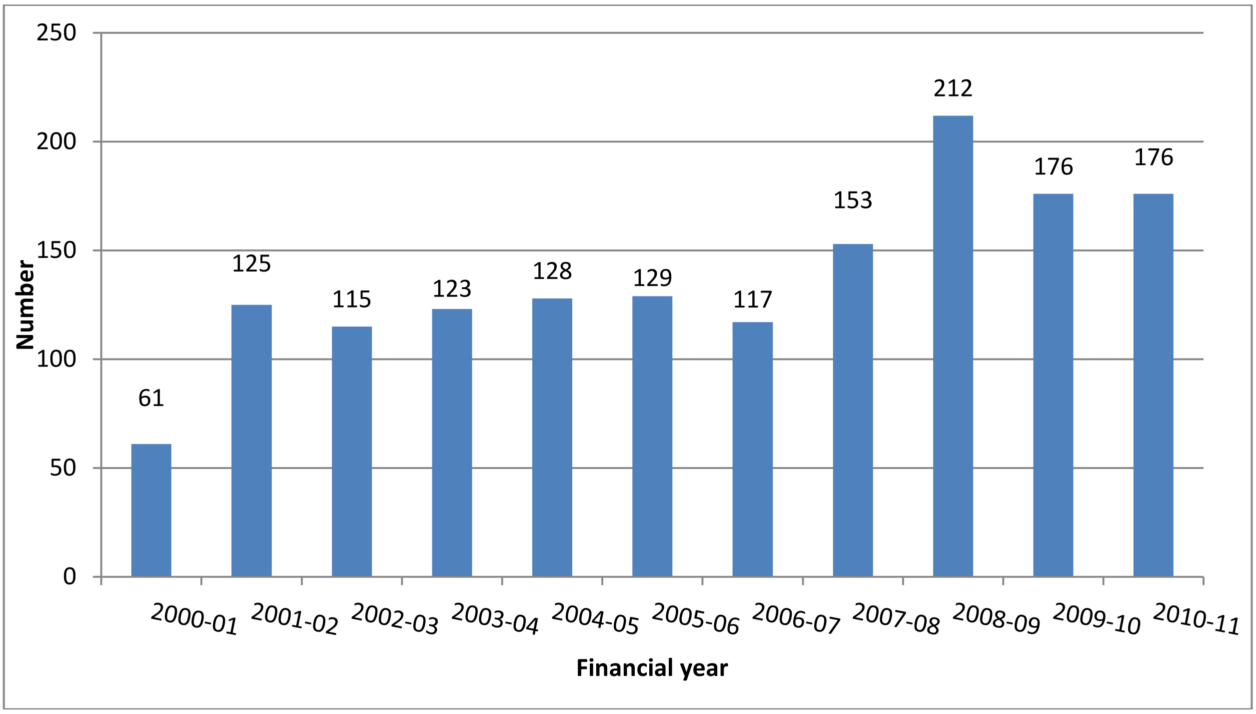


Figure 2-3.9: Number of special all-terrain vehicle related injury hospitalisations by year, NSW APDC, 2000-01 to 2010-11



Of the special all-terrain vehicle related hospitalisations that were identified, 213 (14.1%) were indicated to involve a 'four-wheeled special all-terrain or other off-road motor vehicle', which may include some SSVs and non-ATV off-road vehicles. For the remaining, 1,302 (85.9%) hospitalisations the number of wheels on the special all-terrain vehicle were not specified. The role of the occupant of the special all-terrain vehicle was specified as driver in almost one-third of hospitalisations (28.1%, n=426), 18.6% (n=282) were specified as passengers, 10.3% (n=156) were indicated to be either boarding or alighting the vehicle, 8.7% (n=132) were stated to be persons on the outside of the vehicle, and for 34.3% (n=519) of hospitalisations the role of the occupant of the vehicle was not specified.

The most common principal diagnoses recorded for individuals who were admitted to hospital following a special all-terrain vehicle related crash were injuries to the head (19.5%), injuries to the knee and lower leg (15.1%), and injuries to the thorax (13.2%) (Figure 2-3.10). The type of principal injury sustained varied by occupant role. Injuries to the knee and lower leg (23.8%) and injuries to the elbow and forearm (20.2%) were most common for passengers compared to both drivers (15.3% and 9.6%, respectively) and unspecified occupants (13.9% and 2.9%, respectively). Head injuries and injuries to the thorax were most common for drivers (24.9% and 9.9%, respectively) and unspecified occupants (25.0% and 9.6%, respectively) compared to passengers (12.8% and 1.8%, respectively) (Figure 2-3.11).

Figure 2-3.10: Proportion of principal diagnosis for special all-terrain vehicle related hospitalisations in NSW by injury type, NSW APDC, 2000-01 to 2010-11

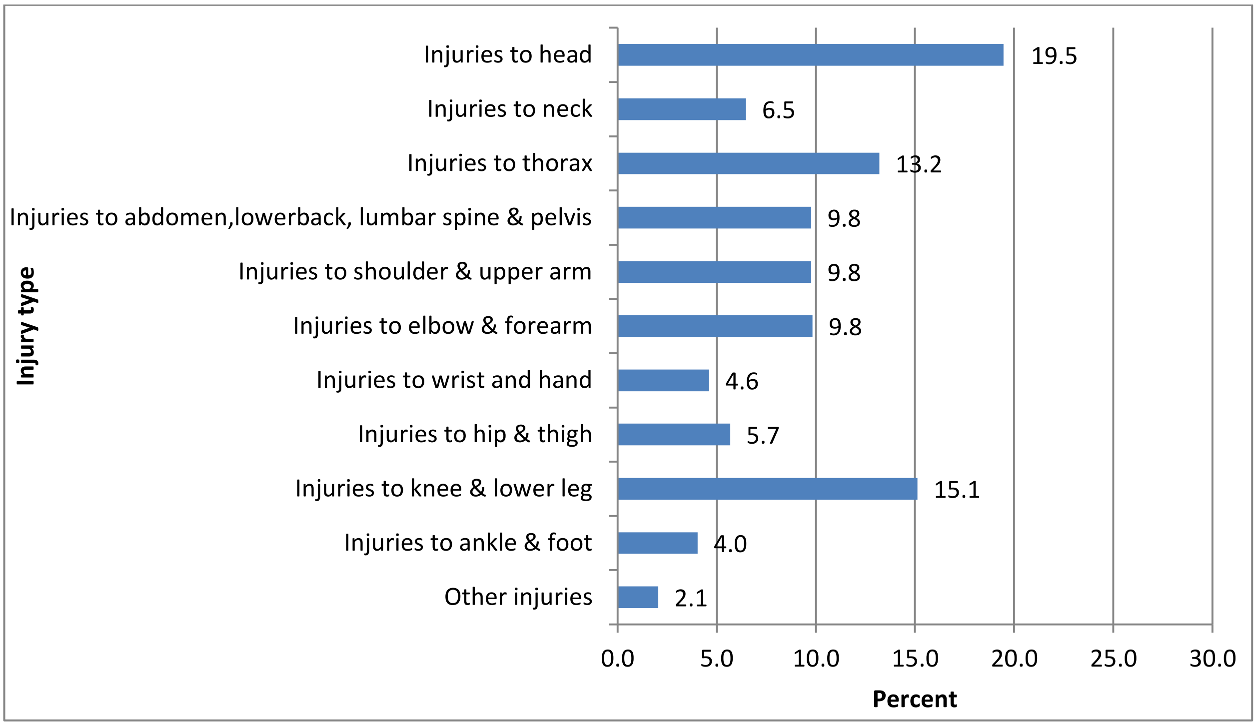
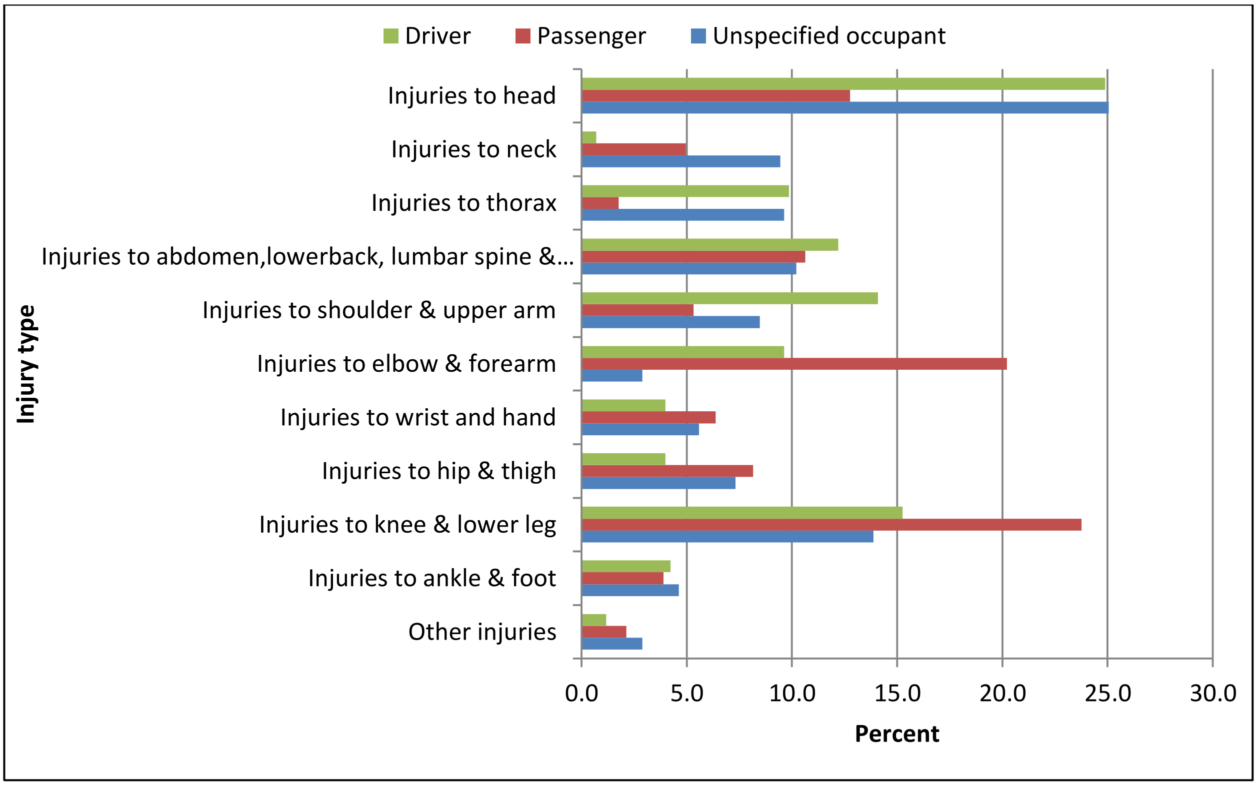


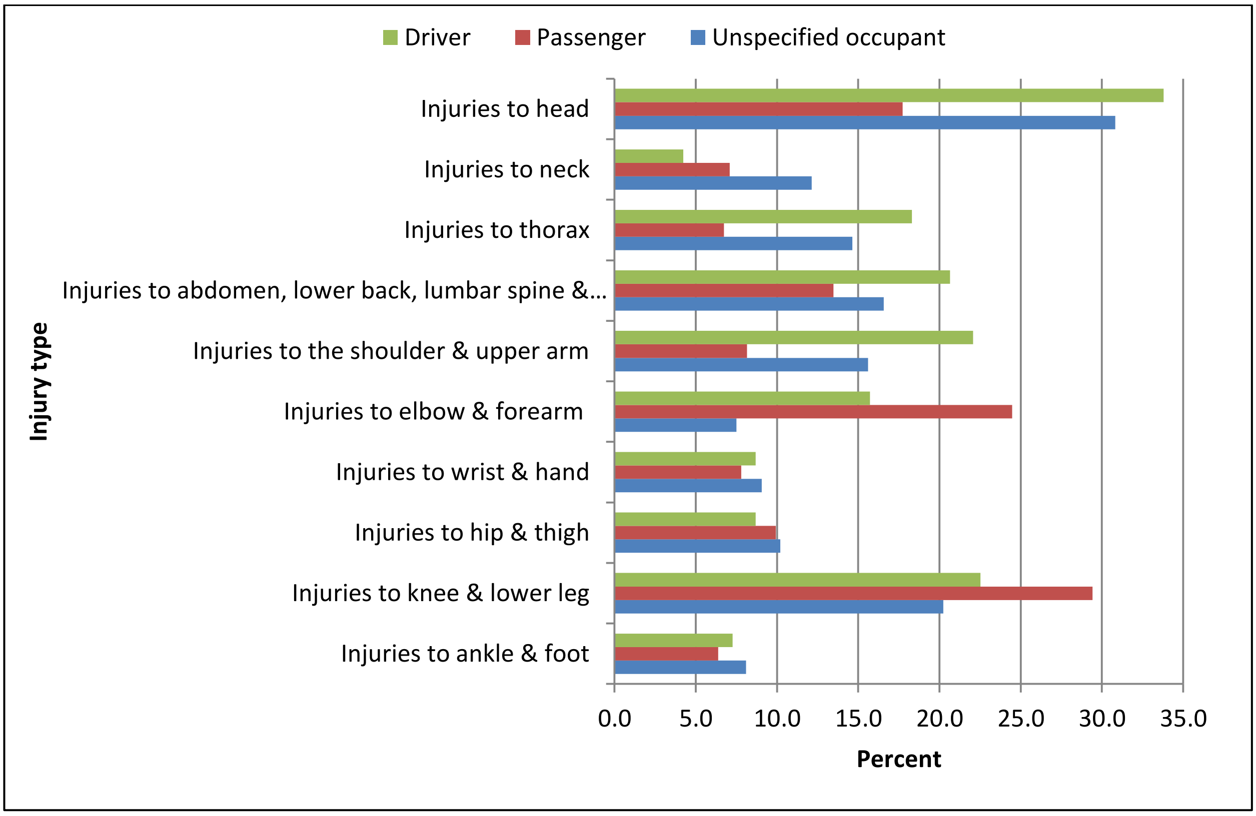
Figure 2-3.11: Proportion of principal diagnosis for special all-terrain vehicle related hospitalisations in NSW by injury type and occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle.

Examination of the first 20 injury diagnosis classifications for each of the occupant types, showed that overall, injuries to the head and thorax were most common for drivers (33.8% and 18.3%, respectively) and unspecified occupants (30.8% and 14.6%, respectively) compared to passengers (17.7% and 6.7%, respectively). Injuries to the shoulder and upper arm were common for drivers (22.1%) compared to passengers and unspecified occupants (8.2% and 15.6%, respectively). Overall, injuries to the knee and lower leg and injuries to the elbow and forearm were most common for passengers (29.4% and 24.5%, respectively) compared to both drivers (22.5% and 15.7%, respectively) and unspecified occupants (20.2% and 7.5%, respectively) (Figure 2-3.12).

Figure 2-3.12: Proportion of injury diagnoses for the first 20 injury diagnosis classifications for special all-terrain vehicle related hospitalisations in NSW by injury type and occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle. Includes multiple injuries per person.

Where the injury was recorded as the principal diagnosis, the most common nature of injury was a fracture (47.6%), open wounds (13.3%) and injuries to internal organs (8.7%) (Figure 2-3.13). Nature of injury varied by occupant role, with fractures most common in passengers (53.9%) or drivers (47.4%) compared to unspecified occupants (30.4%). Injury to internal organs was more common for drivers (21.4%) compared to both passengers and unspecified occupants (4.6% and 2.3%, respectively) (Figure 2-3.14).

Figure 2-3.13: Proportion of principal diagnosis for special all-terrain vehicle related injury hospitalisations in NSW by nature of injury, NSW APDC, 2000-01 to 2010-11

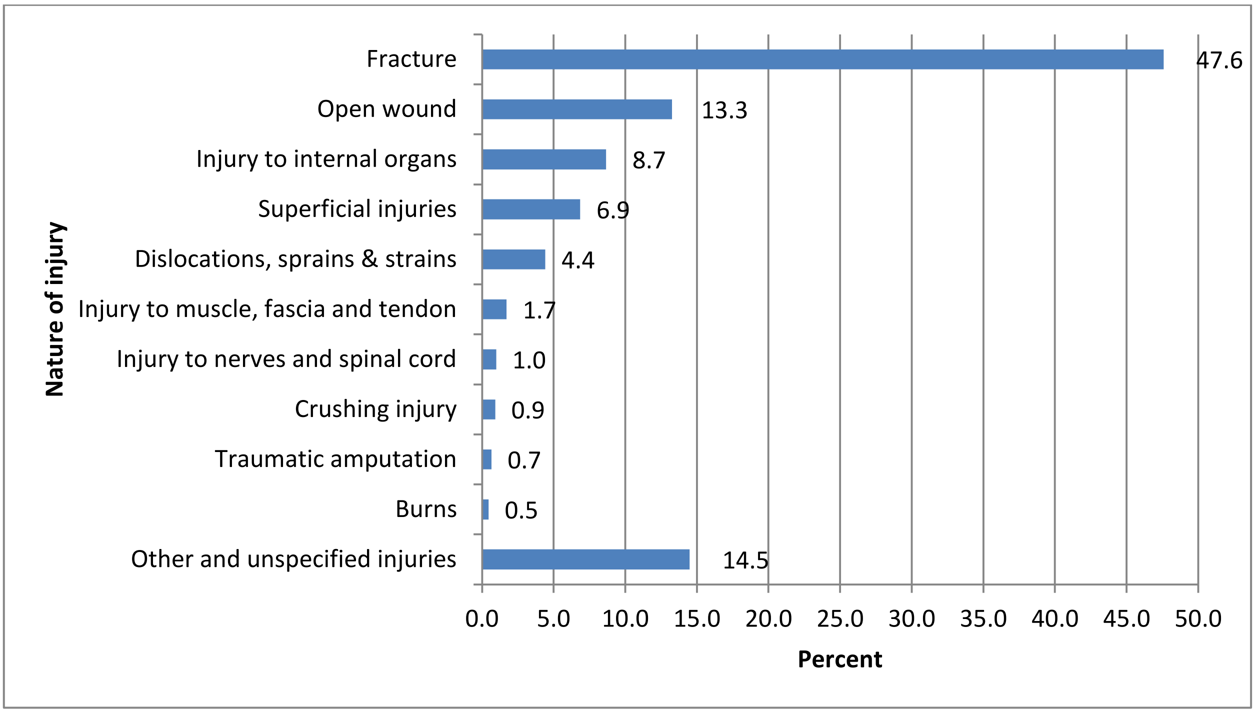
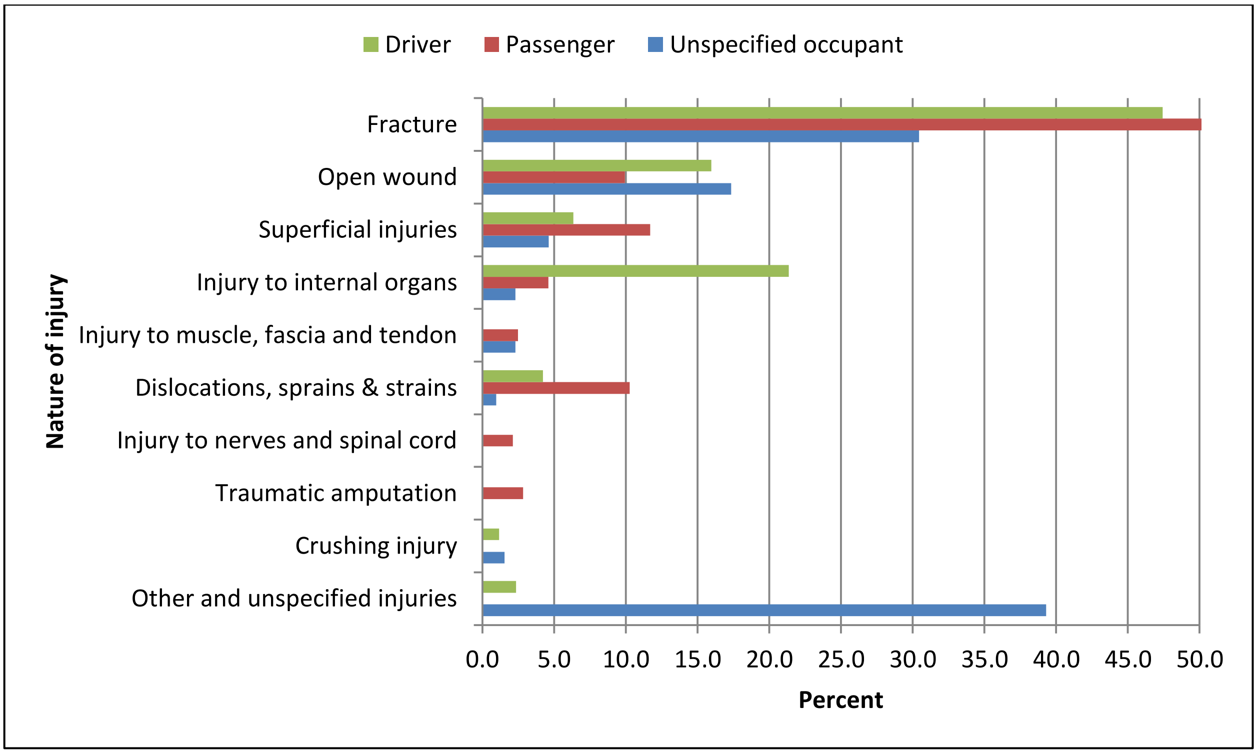


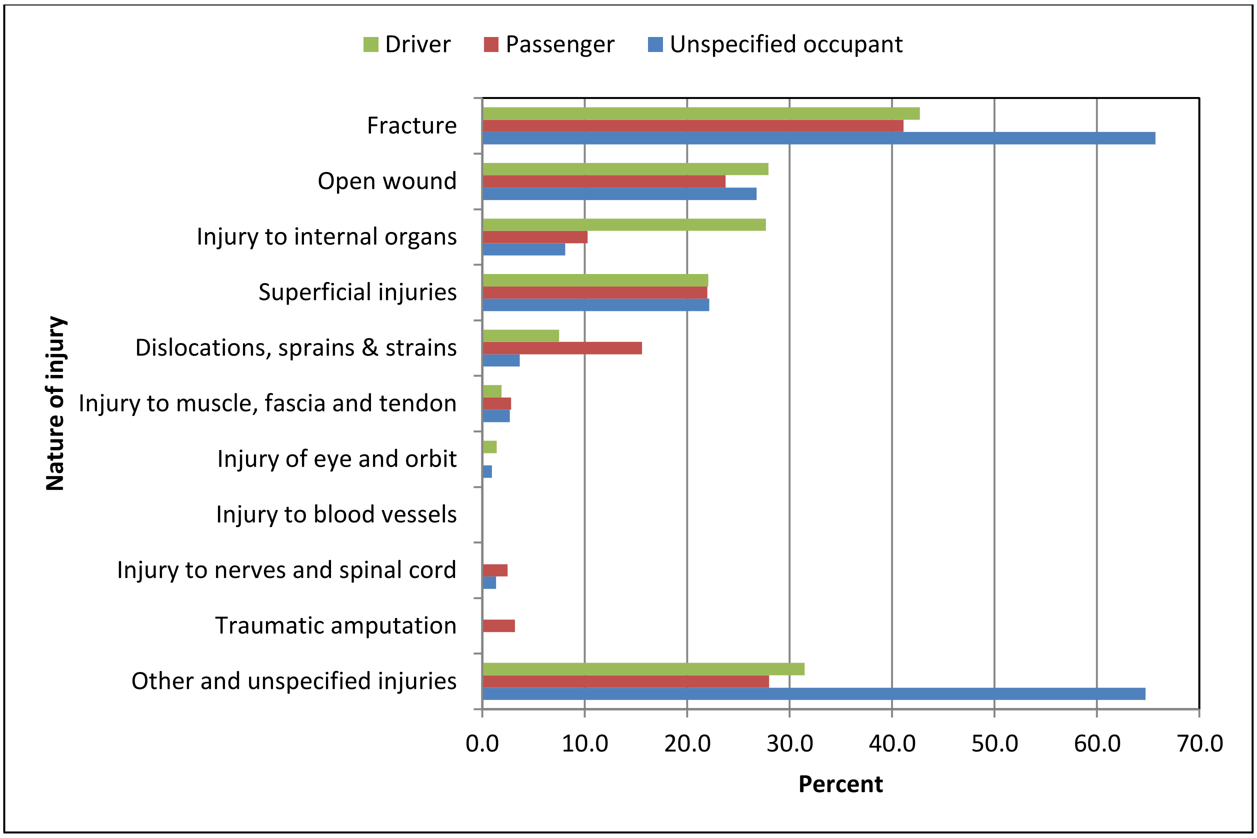
Figure 2-3.14: Proportion of principal diagnosis for special all-terrain vehicle related injury hospitalisations in NSW by nature of injury and occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle. Some values removed as cell sizes less than 5 or to present identification of cell sizes less than 5.

Examination of the first 20 injury diagnosis classifications for each of the occupants, showed that overall, fractures were the most common nature of injury experienced by all occupants. Injury to internal organs was more common overall for drivers (27.7%) compared to both passengers (10.3%) and unspecified occupants (8.1%). Superficial injuries were sustained relatively equally by all occupants (Figure 2-3.15).

Figure 2-3.15: Proportion of injury diagnoses for the first 20 injury diagnosis for special all-terrain vehicle related injury hospitalisations in NSW by nature of injury and occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle. Some values removed as cell sizes less than 5 or to present identification of cell sizes less than 5. Includes multiple injuries per person.

Work related special all-terrain vehicle related injury hospitalisations

There were 179 work related special all-terrain vehicle related injury hospitalisations identified during 1 July 2000 to 30 June 2011 in the APDC. This represented 11.8% of all special all-terrain vehicle related injury hospitalisation. Of the work related incidents, 83.2% (n=149) incidents involved males and 30 (16.8%) incidents involved females. The mean age of the injured individual was 45.6 years (range: 7-93 years). One-third of work related hospitalisations involved individuals aged 55 years and older (Figure 2-3.16).

The number of work related special all-terrain vehicle related incidents identified in the APDC varied by year, with an average of 16 hospitalisations per year (Figure 2-3.17). Median length of stay in hospital was 1 day (range: 1 to 65 days). The majority of individuals who were hospitalised were either discharged (69.3%, n=124) or transferred to another facility (30.2%, n=54). One (0.6%) individual was indicated to have died.

Figure 2-3.16: Number of work related special all-terrain vehicle related injury hospitalisations by age group, NSW APDC, 2000-01 to 2010-11

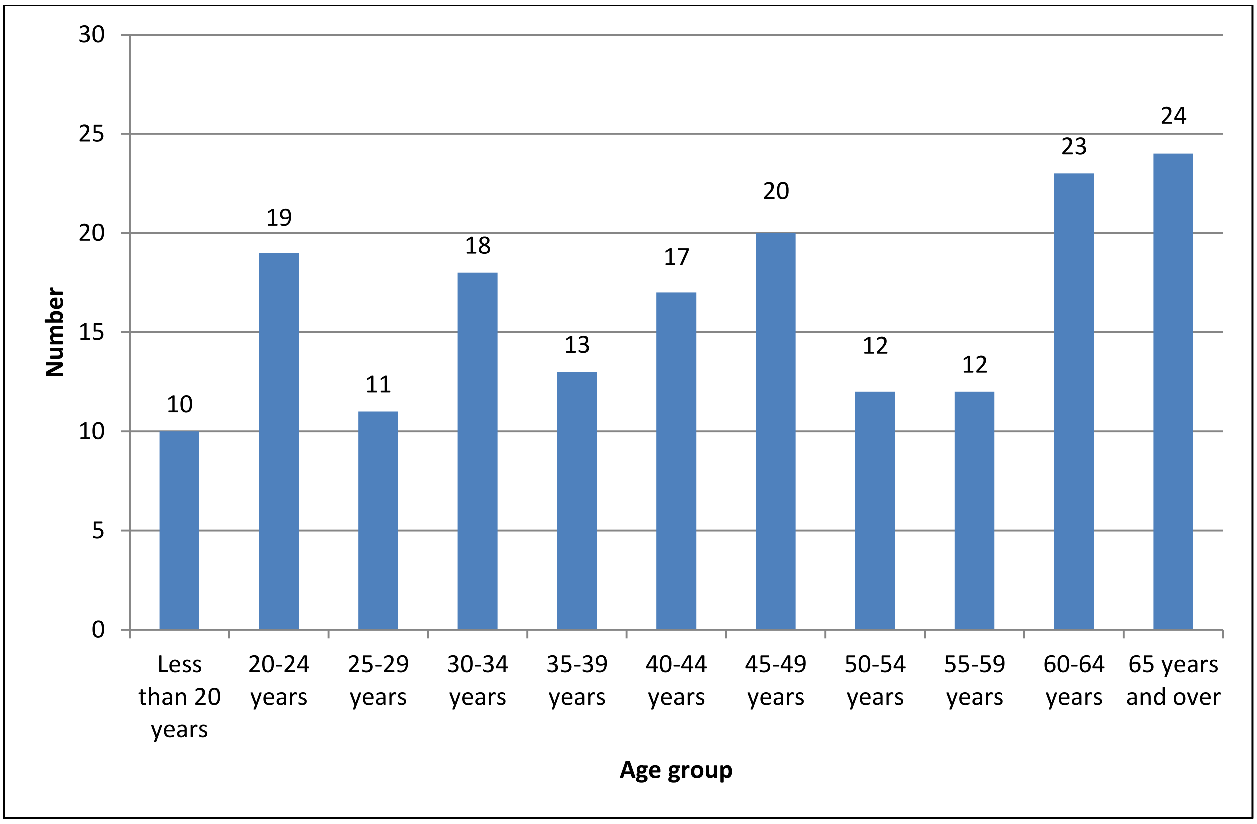
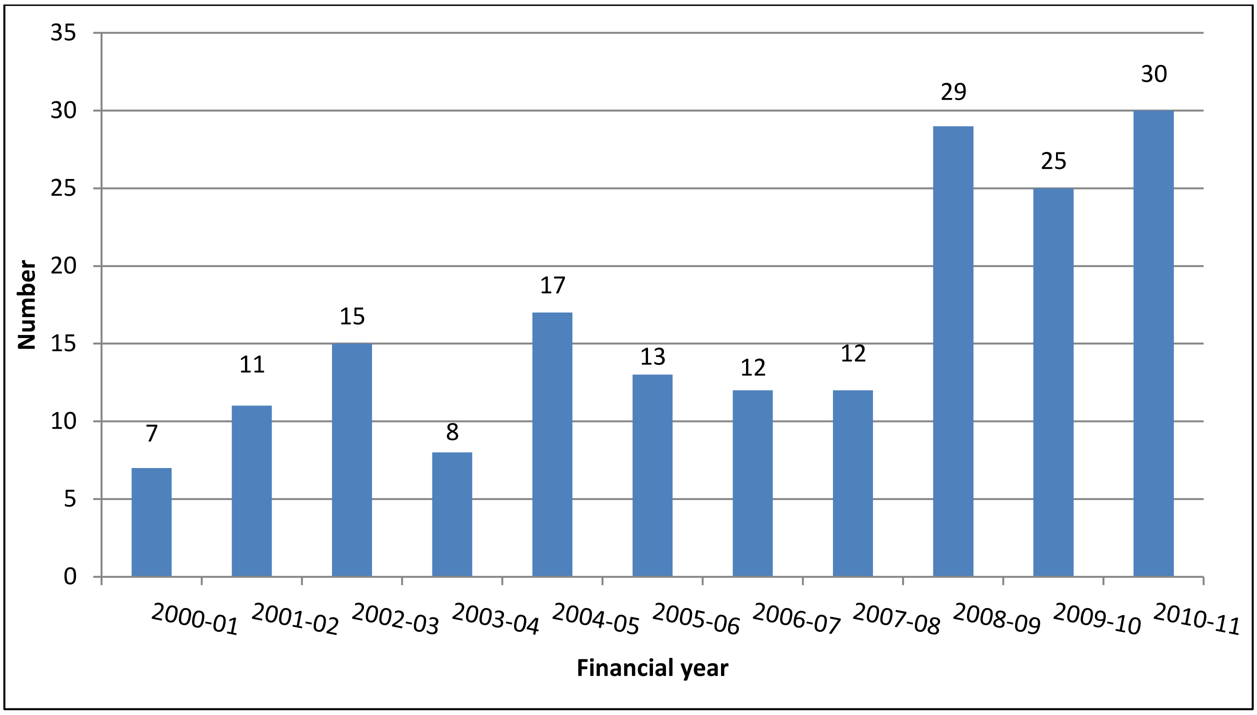


Figure 2-3.17: Number of work related special all-terrain vehicle related injury hospitalisations by year, NSW APDC, 2000-01 to 2010-11



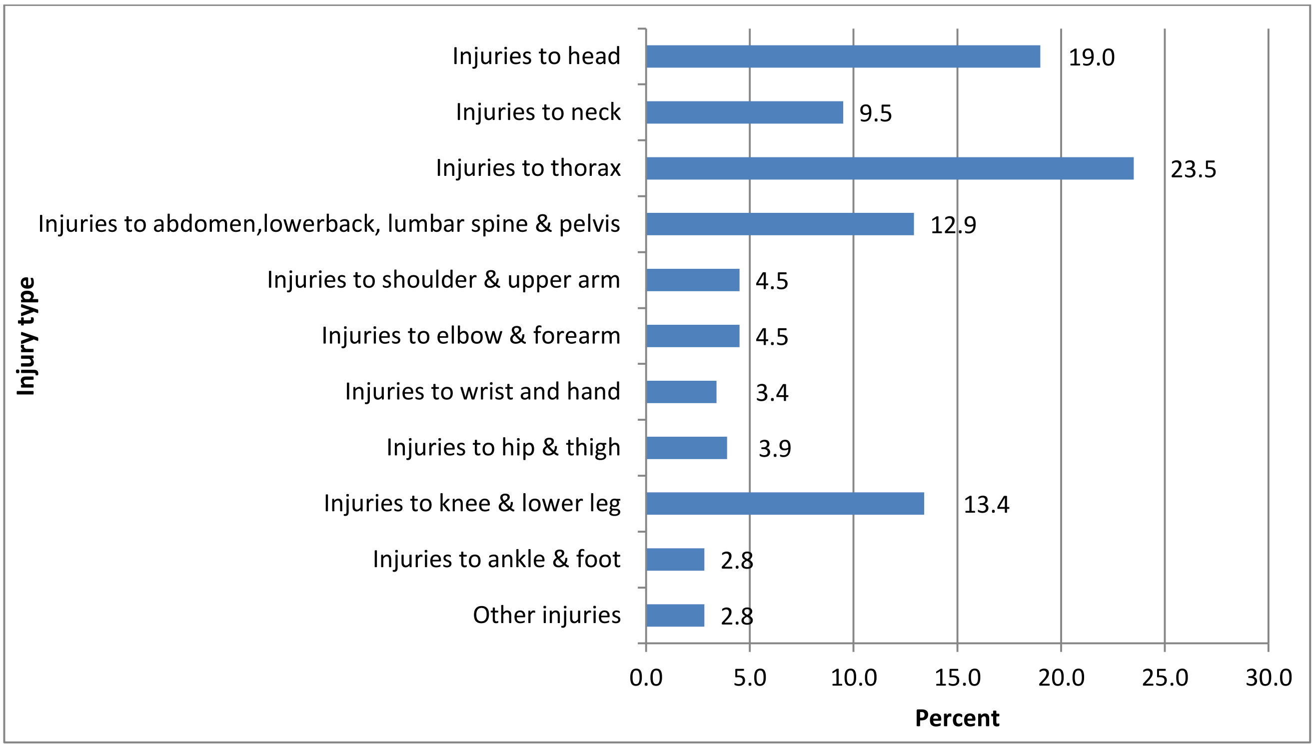
Of the work related special all-terrain vehicle related hospitalisations that were identified, 21 (11.7%) were indicated to involve a 'four-wheeled special all-terrain or other off-road motor vehicle', which may include some SSVs and non-ATV off-road vehicles. For the remaining, 158 (88.3%) hospitalisations the number of wheels on the special all-terrain vehicle were not specified.

The role of the occupant of the work related special all-terrain vehicle was specified as driver in just less than one-quarter of hospitalisations (22.9%, n=41), 19.0% (n=34) were specified as passengers[2], 14.0% (n=25) were indicated to be either boarding or alighting the vehicle, 12.9% (n=23) were stated to be persons on the outside of the vehicle, and for 31.3% (n=56) of hospitalisations the role of the occupant of the vehicle was not specified.

The most common principal diagnoses recorded for individuals who were admitted to hospital following a special all-terrain vehicle related crash were injuries to the thorax (23.5%), injuries to the head (19.0%), injuries to the knee and lower leg (13.4%), and injuries to the abdomen, lower back, lumbar spine and pelvis (12.9%) (Figure 2-3.18).

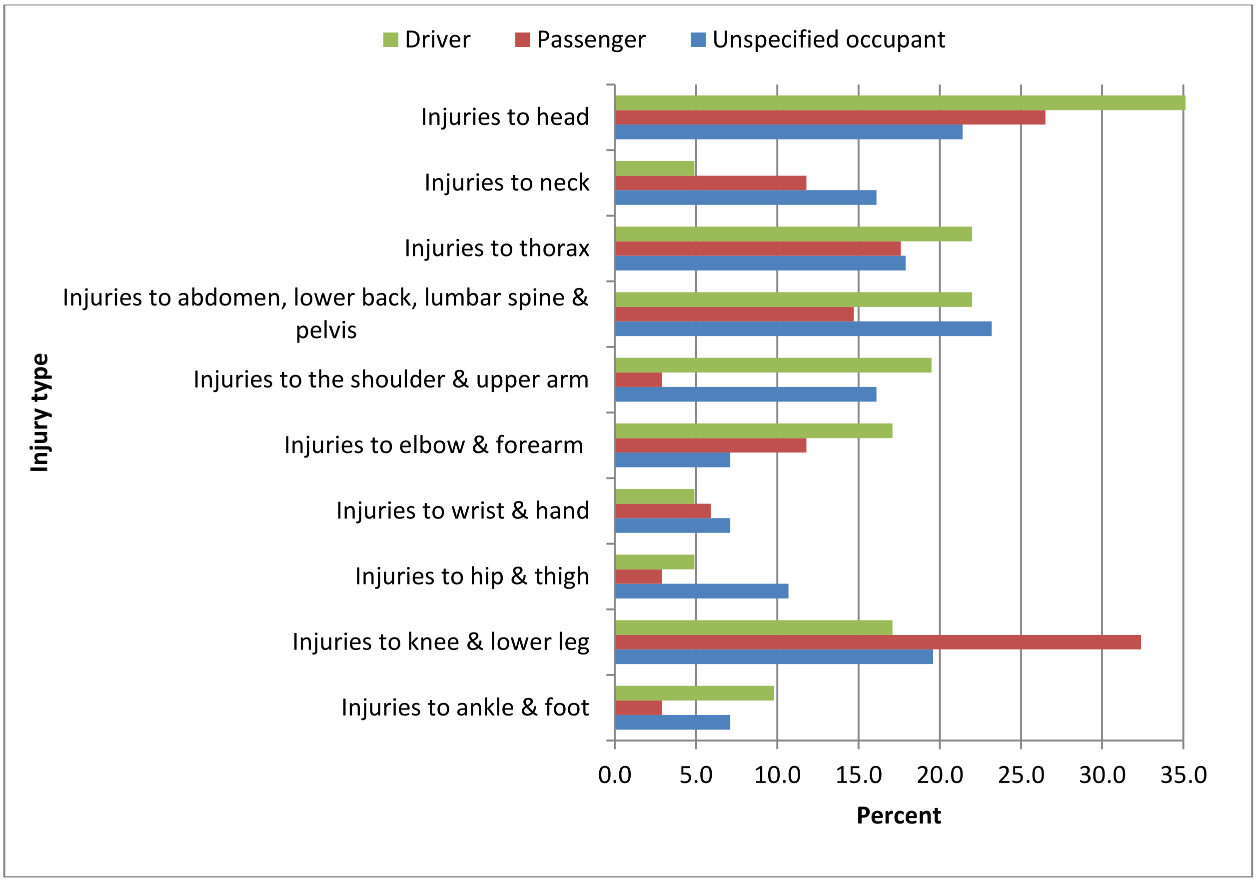
[2] Note that most Quad bikes are not designed to carry passengers and this is a 'warned-against behaviour' on the warning labels of nearly all ATVs.

Figure 2-3.18: Proportion of principal diagnosis for work related special all-terrain vehicle related hospitalisations in NSW by injury type, NSW APDC, 2000-01 to 2010-11



Examination of the first 20 injury diagnosis classifications for each of the work related occupant types, showed that overall, injuries to the head and thorax were most common for drivers (43.9% and 22.0%, respectively) compared to passengers (26.5% and 17.6%, respectively) and unspecified occupants (21.4% and 17.9%, respectively). Injuries to the shoulder and upper arm were common for drivers (19.5%) and unspecified occupants (16.1%) compared to passengers (2.9%). Overall, injuries to the knee and lower leg were most common for passengers (32.4%) compared to both drivers (17.1%) and unspecified occupants (19.6%) (Figure 2-3.19).

Figure 2-3.19: Proportion of injury diagnoses for the first 20 injury diagnosis classifications for work related special all-terrain vehicle related hospitalisations in NSW by injury type and occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle. Includes multiple injuries per person.

Where the injury was recorded as the principal diagnosis, the most common nature of injury was a fracture (45.8%), injuries to internal organs (10.1%), and open wounds (7.8%) (Figure 2-3.20). Examination of the first 20 injury diagnosis classifications for each of the work related occupants showed that overall, where the nature of injury was specified, fractures were the most common nature of injury experienced by all occupants. Injury to internal organs was more common overall for drivers (34.1%) compared to both passengers (8.8%) and unspecified occupants (1.8%) (Figure 2-3.21).

Figure 2-3.20: Proportion of principal diagnosis for work related special all-terrain vehicle related injury hospitalisations in NSW by nature of injury, NSW APDC, 2000-01 to 2010-11

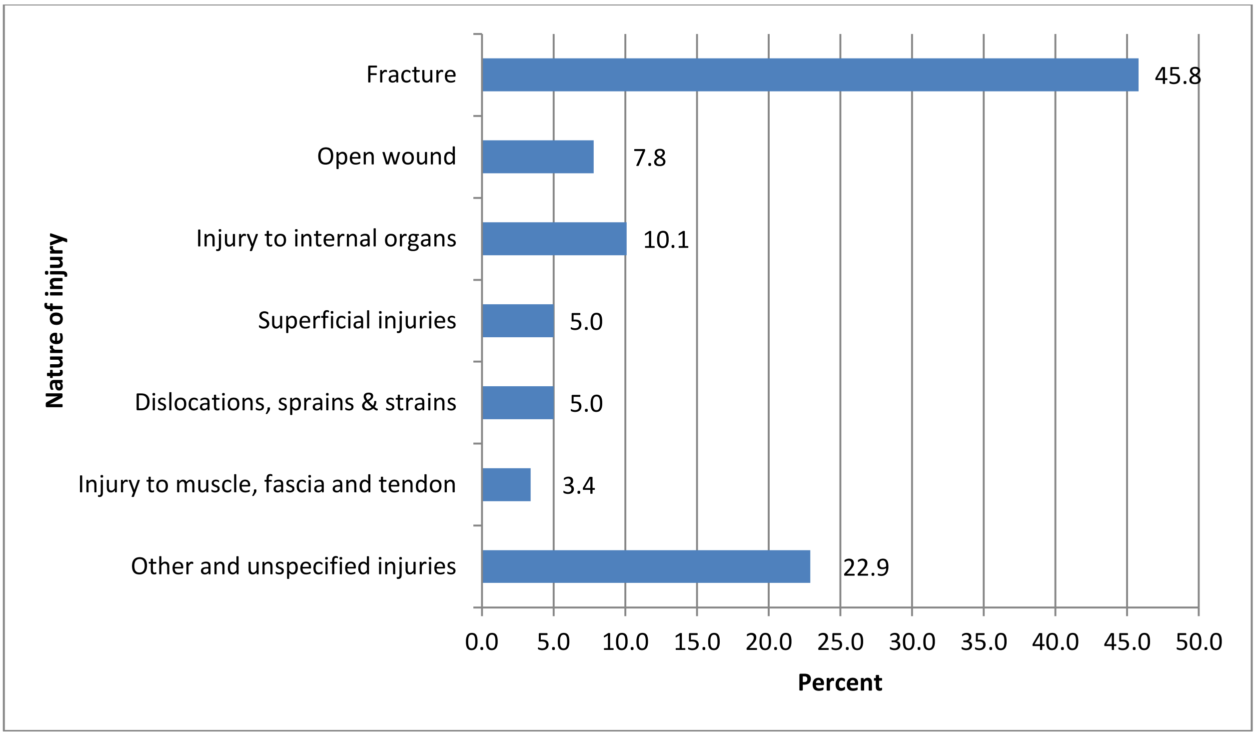
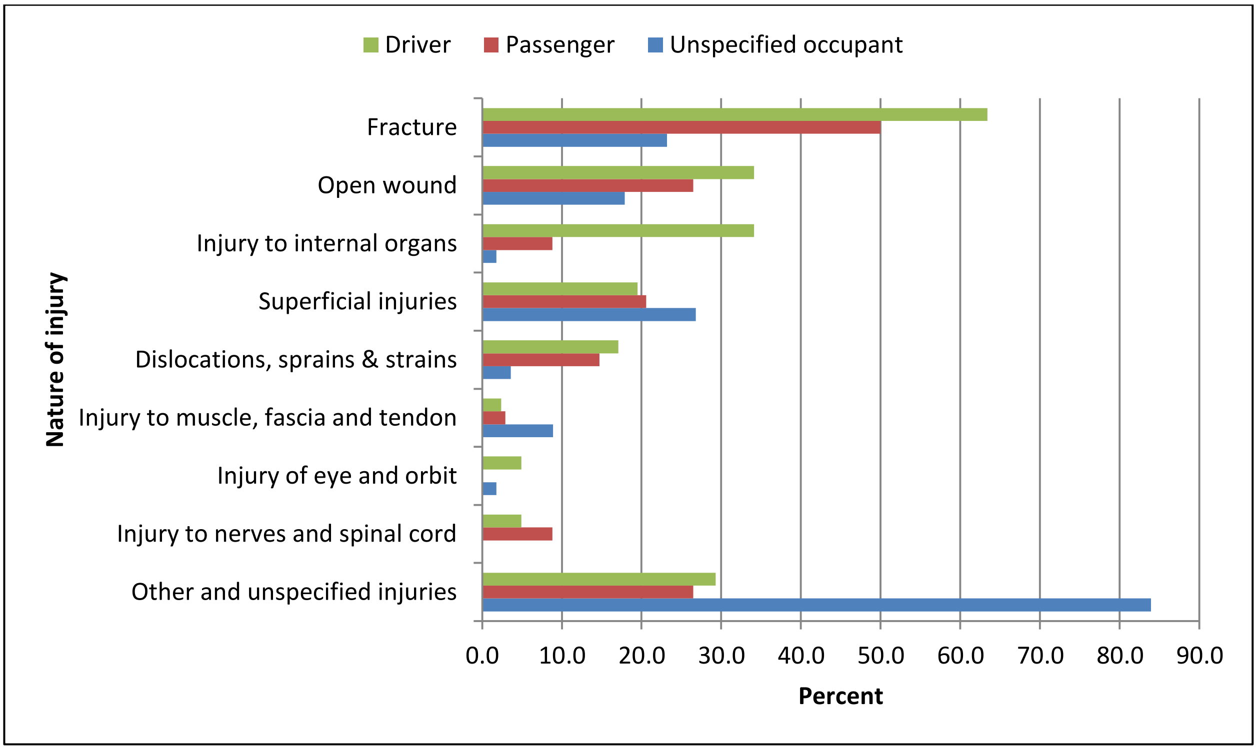


Figure 2-3.21: Proportion of injury diagnoses for the first 20 injury diagnosis for work related special all-terrain vehicle related injury hospitalisations in NSW by nature of injury occupant type[1], NSW APDC, 2000-01 to 2010-11



[1] Excludes person on outside of vehicle and person boarding or alighting vehicle. Includes multiple injuries per person.

3.6 Quad bike related injury in the NSW Public Health Real-time Emergency Department Surveillance System

During 1 January 2006 to 31 December 2012 there were 12,891,941 ED presentations recorded in the PHREDSS. The keyword text search of all ED presentations identified 3,721 potential Quad bike related presentations to the EDs (Table 2-3.18). Of the 3,721 potential Quad bike presentations, 3,351 (90.1%) were confirmed as either true Quad bike, side by side or small non-adult Quad bike related ED presentations after reviewing narrative descriptions from nurse triage assessment and presenting problem data fields (Table 2-3.19). Of the 3,351 presentations, 40 (1.2%) were identified as small non-adult Quad bikes, 11 (0.3%) were identified as side by side vehicles and the remaining 3,300 (98.5%) were identified as Quad bike related presentations. It is possible that some of the 3,300 Quad bikes were small non-adult Quad bikes or side by side vehicles, but the narrative text did not indicate these specific vehicle types.

Table 2-3.18: Identification of Quad bike keywords in the PHREDSS, 2006-2012

Keyword[1]	Person	
	n	%[2]
QUAD and BIKE	3,586	96.4
QUAD and BIKING	3	0.1
ATV	126	3.4
ALL-TERRAIN	3	0.1
ALL-TERRAIN	3	0.1
TOTAL	**3,721**	**100.0**

[1] ATV: All-terrain vehicle.

[2] Percent of ED presentations relating to Quad bike injuries that were identified on the basis of the keyword.

Table 2-3.19: Proportion of records that were identified as being true Quad bike, side by side or small non-adult Quad related in the PHREDSS by keyword, 2006-2012

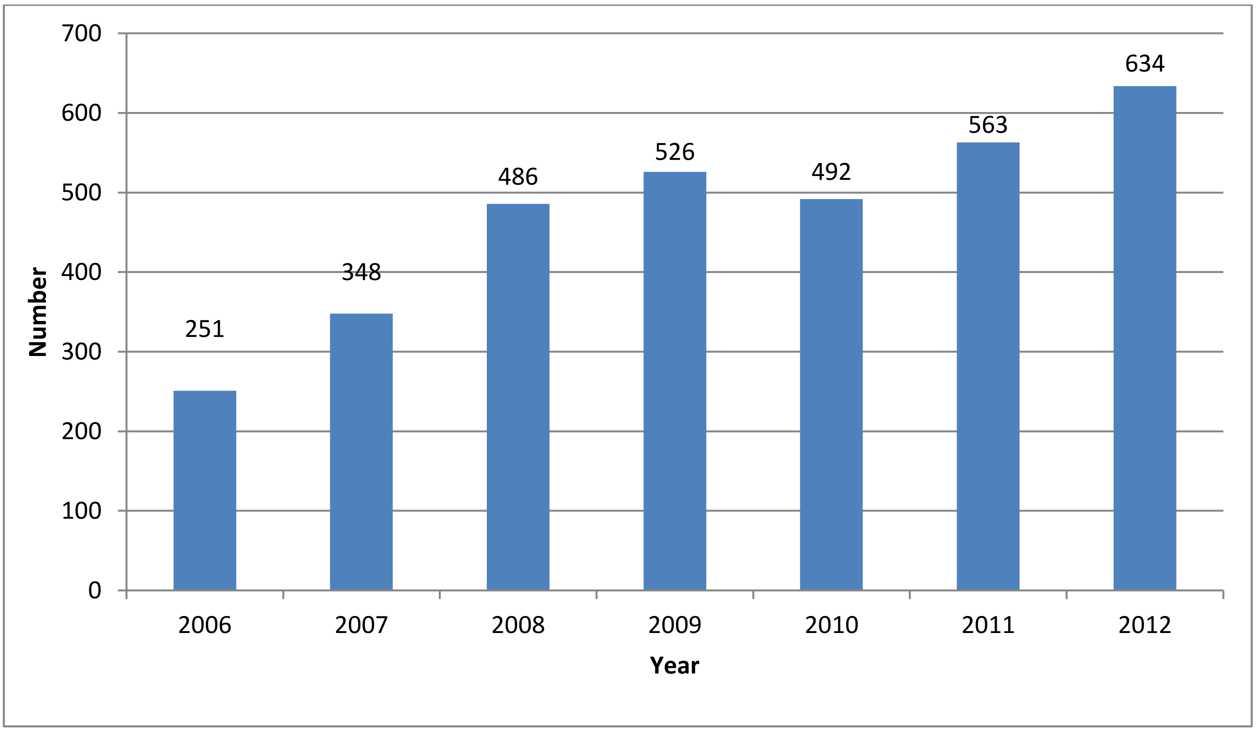
Quad bike[1]	n	%[2]
QUAD and BIKE	3,332	92.9
QUAD and BIKING	3	100.0
ATV	10	7.9
ALL-TERRAIN	3	100.0
ALL-TERRAIN	3	100.0
TOTAL	**3,351**	**90.1**

[1] ATV: All-terrain vehicle.

[2] Percent of ED presentations identified as road trauma on the basis of the keyword search that were confirmed to be relating to road trauma on the basis of a review of the narrative text.

For the 3,300 individuals that presented to an ED for a Quad bike related injury, the number of presentations generally increased each year, except for 2010 (Figure 2-3.22). There were 2,300 (69.7%) males and 1,000 (30.3%) females that presented to an ED for a Quad bike related injury. The 25-34 year old and 10-14 year old age groups had the highest proportion of Quad bike related ED presentations (14.6% and 13.8%, respectively). There were 493 (15.0%) ED presentations of children aged 9 years or less (Figure 2-3.23). The mean age of injured individuals was 28.7 years.

Figure 2-3.22: Number of Quad bike related ED presentations by year, PHREDSS 2006 to 2012[1]



[1] Note: The number of EDs providing information to PHREDSS increased from n=38 in 2006 to n=59 in 2012 and some hospitals had incomplete reporting over the period.

Almost all (98.2%) ED presentations were identified as emergency presentations, 22 (0.7%) were unplanned returns to the ED, 16 (0.5%) were planned returned visits, 9 (0.3%) were privately referred patients, and 9 (0.3%) were other and unspecified presentations. Two patients were deceased on arrival at the ED. The majority of individuals arrived at the ED via a private vehicle (66.4%) or the NSW ambulance service (23.2%) (Figure 2.24).

Figure 2-3.23: Number of Quad bike related ED presentations by age group, PHREDSS 2006 to 2012

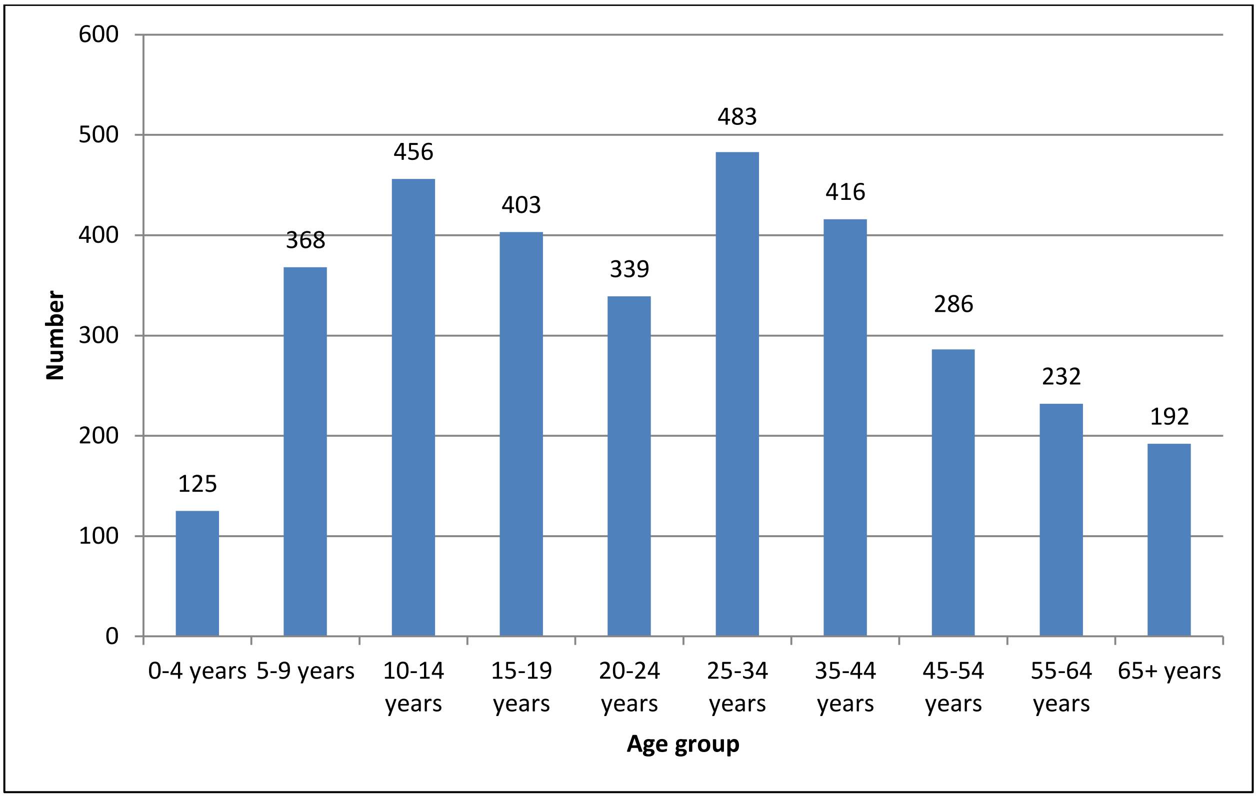
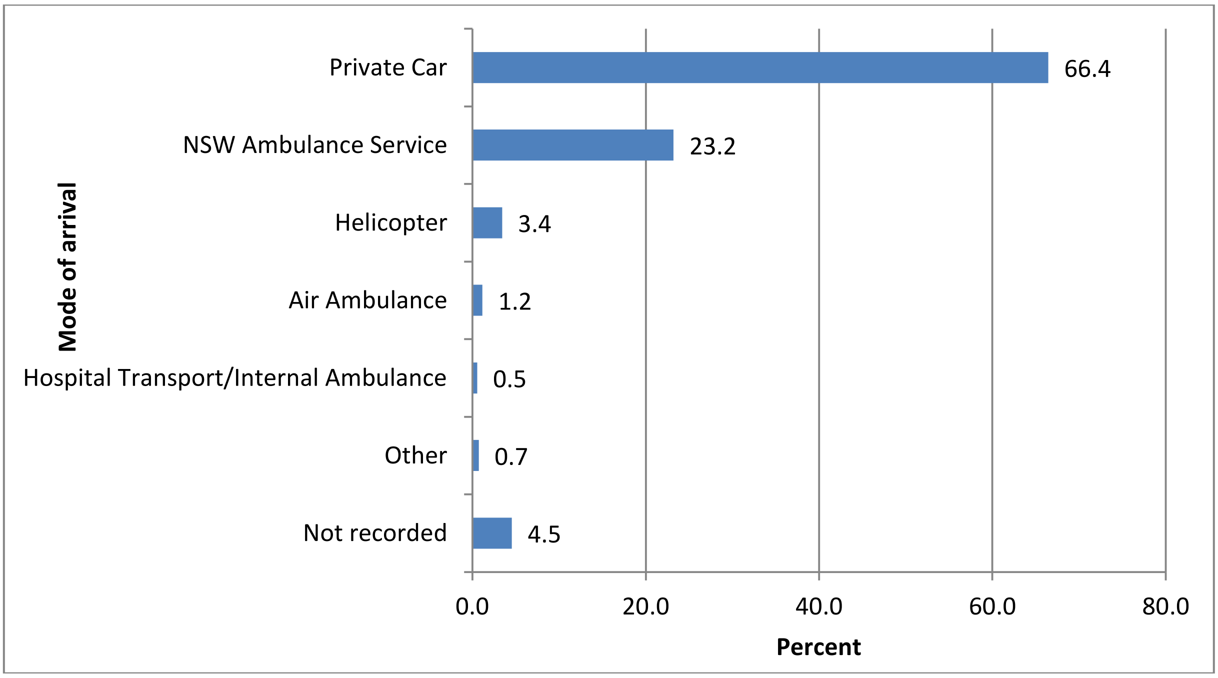
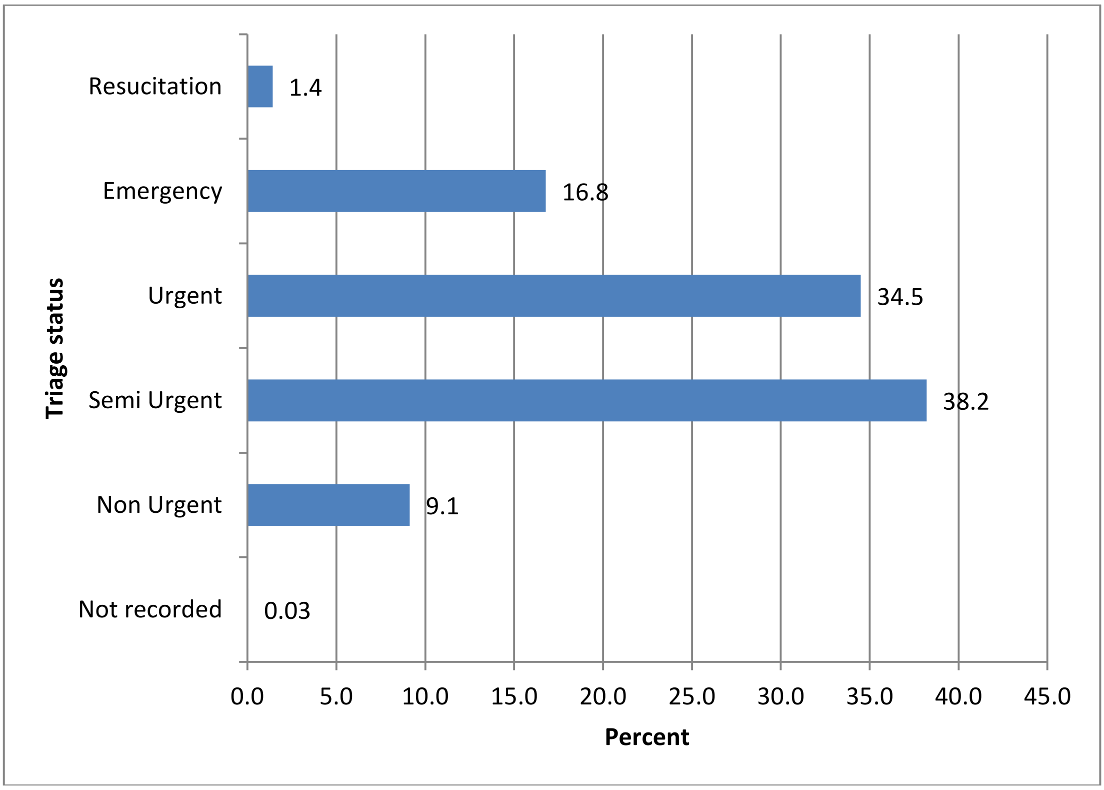


Figure 2-3.24: Percent of Quad bike related ED presentations by arrival mode, PHREDSS 2006 to 2012



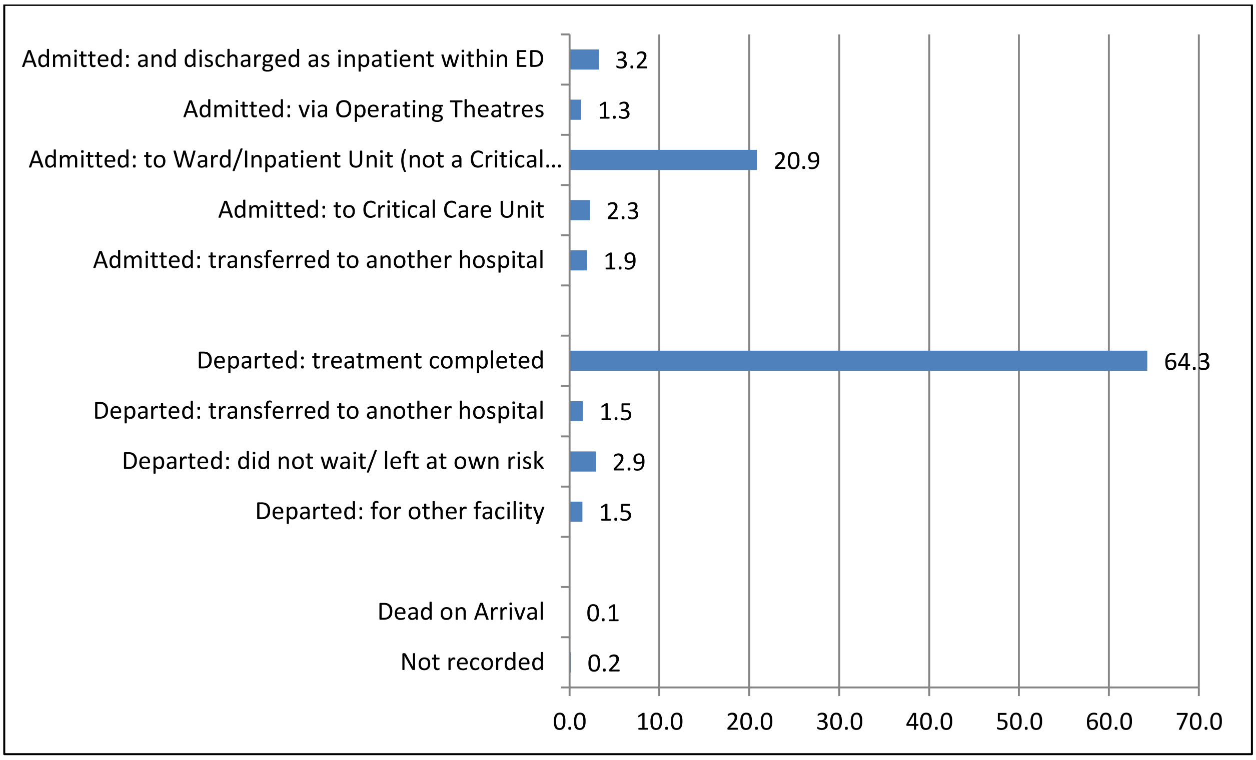
Triage ratings in the ED are based on a number of criteria including mechanism of injury, the individual's vital signs at the time of presentation, and age. Triage status within the ED was most commonly rated as semi-urgent (i.e. treatment within 60 minutes) (38.2%), urgent (i.e. treatment within 30 minutes) (34.5%), or an emergency (i.e. treatment within 10 minutes) (16.8%) (Figure 2-3.25). Only 1.4% of individuals required resuscitation (i.e. treatment within seconds) and 9.1% were identified as non-urgent (i.e. treatment within 120 minutes). The triage status of one individual was not recorded.

Figure 2-3.25: Percent of Quad bike related ED presentations by triage status, PHREDSS 2006 to 2012



The majority of individuals who presented to the ED for a Quad bike related injury were treated and/or assessed and departed the ED (70.2%). Thirty percent of individuals were admitted to hospital following the incident. Of the hospital admissions, 20.9% were admitted to a general ward (Figure 2-3.26).

Figure 2-3.26: Percent of Quad bike related ED presentations by departure status, PHREDSS 2006 to 2012



Information on the identification of injuries sustained by individuals in Quad bike incidents were identified through keyword searches for common types of injuries in a provisional diagnosis classification narrative text field. Keyword searches identified 909 (27.1%) fractures, 302 (9.0%) lacerations, 207 (6.2%) open wounds, 111 (3.3%) contusions, 73 (2.2%) dislocations, 63 (1.9%) superficial injuries, 47 (1.4%) head injuries, and 27 (0.8%) sprains and strains. Of the 909 fractures, 122 (13.4%) were fractures of the clavicle.

Where the narrative text specified the type of Quad bike incident, it was indicated that 677 (20.5%) were Quad bike rollovers and 96 (2.9%) were Quad bike runovers. There were 1,493 (45.2%) incidents where it was specified that the individual fell off or jumped off the Quad bike and there were 453 (13.7%) incidents identified where the Quad bike hit an object. Where the type of object struck was specified, these were trees, stumps, logs, poles and posts (4.6%; n=150), fences or gates (3.5%; n=115), ditches, embankments, gullies, holes (1.7%; n=57), other vehicles (1.7%; n=57), rocks, bumps or gutters (1.0%; n=33), walls (0.7%; n=24), animals (0.6%; n=19), jumps or ramps (0.6%; n=19), water (0.3%; n=10) and other objects (0.3%; n=9), such as other individuals, irrigation hoses, trailers.

The activity that the individual was performing at the time of the Quad bike incident was rarely recorded in the narrative text fields (n=156; 4.7%). Where activity information was provided, the individual was identified as riding the Quad bike for recreation on the beach or sand dunes (n=54; 1.6%), at an unspecified location that might have included going over jumps (n=36; 1.1%), or at a motor cross event or on a trail (n=13; 0.4%). In the remaining incidents the individual was identified as using the Quad bike for work, such as mustering or spraying (n=29; 0.9%), other and unspecified work (n=18; 0.6%), or travel for work purposes on a rural property (n=6; 0.2%).

Where the narrative text specified descriptive information regarding features of the incident and/or the individual, it was indicated that 322 (9.8%) individuals were wearing a helmet at the time of the Quad bike incident, although 8 (0.2%) of these individuals were identified as wearing a bicycle helmet. There were 263 (8.0%) individuals who were identified as not wearing a helmet at the time of the incident and for the remaining 2,715 (82.3%) individuals helmet use was not specified. There were 71 (2.2%) Quad bike incidents where the individual was identified as a passenger on the Quad bike and in the remaining incidents (97.9%) the occupant status was not specified. Alcohol consumption was identified in 38 (1.2%) Quad bike incidents, was excluded in one incident and was not specified for almost all incidents (98.8%). Estimated speed of the Quad bike was specified either in kilometres per hour (km/h) or as an estimated range in the narrative text for 740 (22.4%) incidents (Table 2-3.20).

Table 2-3.20: Number of Quad bike related ED presentations where vehicle speed was indicated, PHREDSS 2006 to 2012

Quad bike estimated speed Km/h[1]	Number
0-10	59
11-20	105
21-30	92
31-40	75
41-50	69
51-60	43
61-80	36
81-100	10
>100	7
Not known	50
Estimated range	
Low	163
Moderate	10
High	27

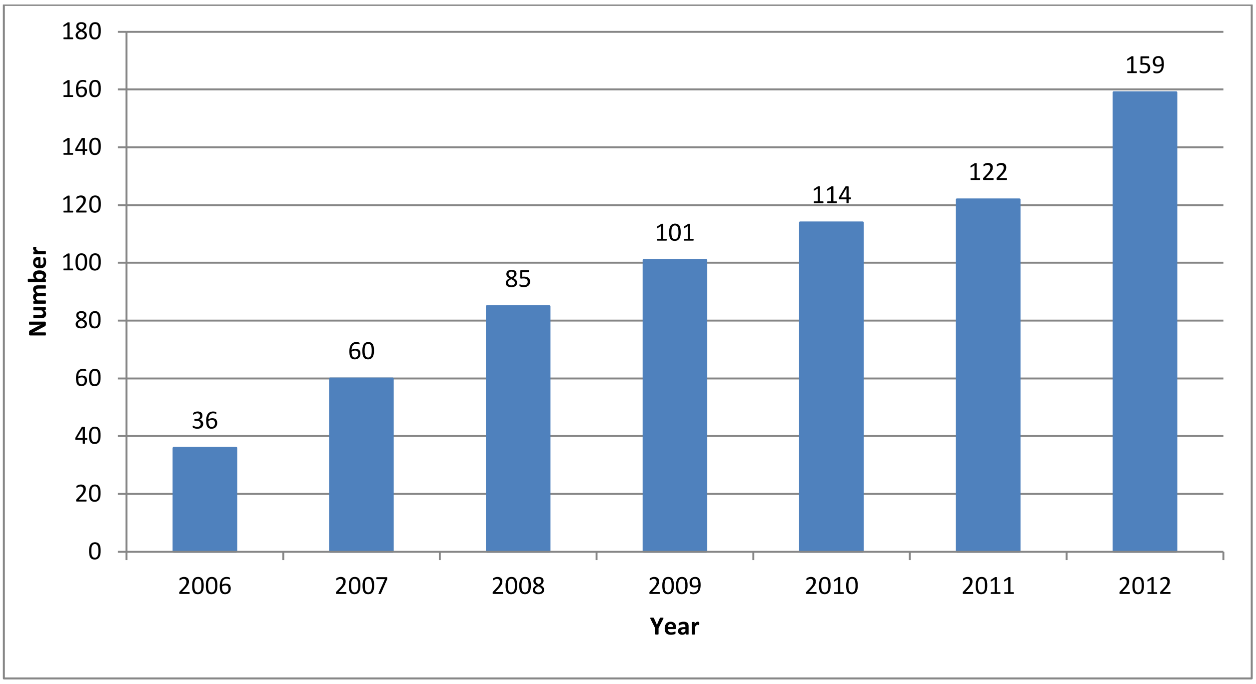
[1] Kilometres per hour.

Quad bike rollovers

There were 677 Quad bike rollovers identified in PHREDSS. For the 677 individuals that presented to an ED for a Quad bike rollover related injury, the number of presentations increased each year (Figure 2-3.27). There were 503 (74.3%) males and 174 (25.7%) females that presented to an ED for a Quad bike rollover related injury. The 45-54 (14.3%) year old, 35-44 year old (13.3%), 25-34 year old and 15-19 year old (12.6%) age groups had the highest proportion of Quad bike rollover related ED presentations. There were 51 (7.5%) ED presentations of children aged 9 years or less (Figure 2-3.28). The mean age of individuals was 33.9 years.

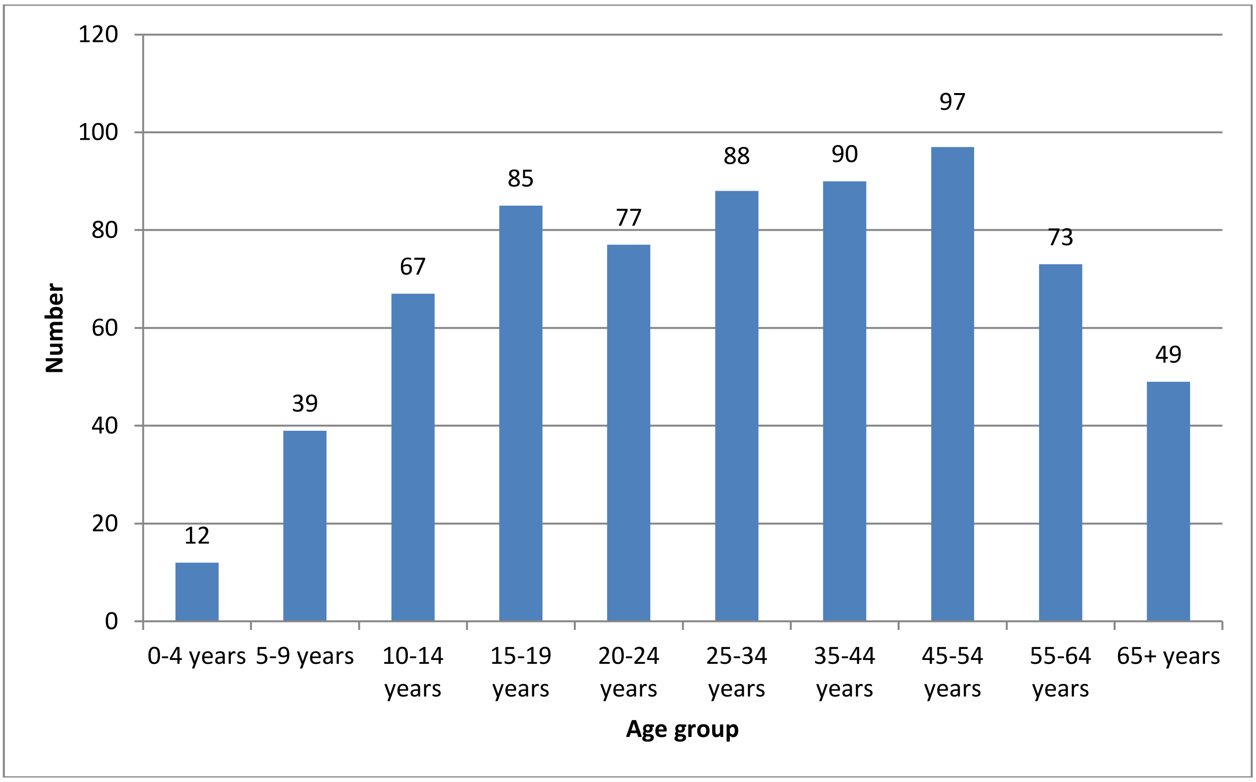
Almost all (99.3%) ED presentations were identified as emergency presentations, with 5 (0.7%) returned visits and/or admissions. The majority of individuals arrived at the ED via a private vehicle (60.1%), the NSW ambulance service (28.7%), or by helicopter or air ambulance (6.2%), with 34 (5.0%) other and unspecified arrival modes.

Figure 2-3.27: Number of Quad bike rollover related ED presentations by year, PHREDSS 2006 to 2012[1]



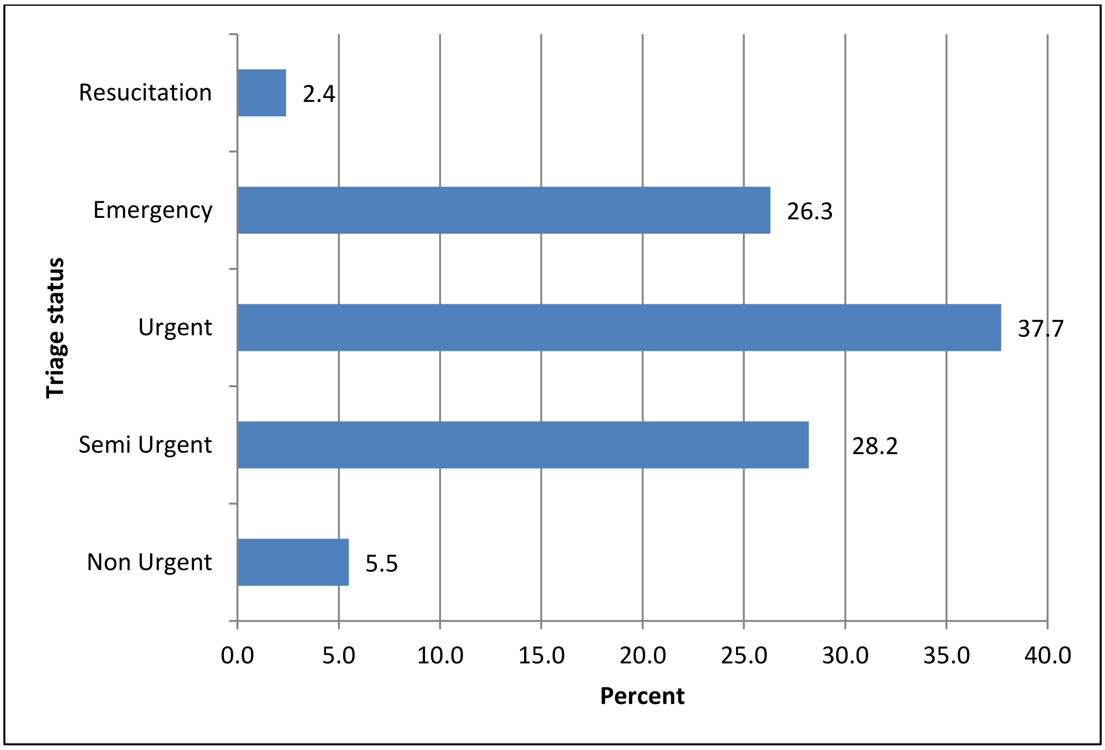
[1] Note: The number of EDs providing information to PHREDSS increased from n=38 in 2006 to n=59 in 2012 and some hospitals had incomplete reporting over the period.

Figure 2-3.28: Number of Quad bike rollover related ED presentations by age group, PHREDSS 2006 to 2012



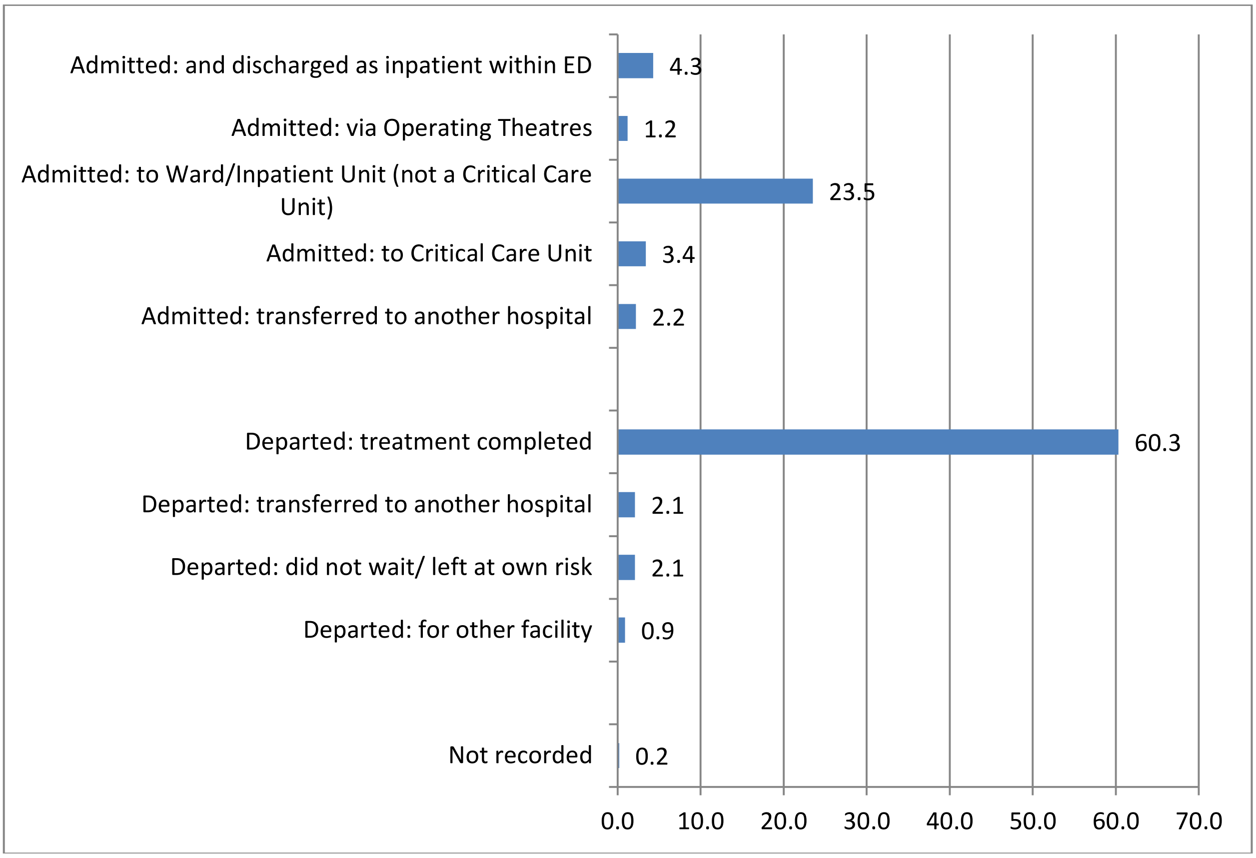
Triage status within the ED for Quad bike rollovers was most commonly rated as urgent (i.e. treatment within 30 minutes) (37.7%), semi-urgent (i.e. treatment within 60 minutes) (28.2%), or an emergency (i.e. treatment within 10 minutes) (26.3%). Only 2.4% of individuals required resuscitation (i.e. treatment within seconds) and 5.5% were identified as non-urgent (i.e. treatment within 120 minutes) (Figure 2-3.29).

Figure 2-3.29: Percent of Quad bike rollover related ED presentations by triage status, PHREDSS 2006 to 2012



The majority of individuals who presented to the ED for a Quad bike related injury were treated and/or assessed and departed the ED (65.4%). Thirty-five percent of individuals were admitted to hospital following the incident. Of the hospital admissions, 23.5% were admitted to a general ward (Figure 2-3.30).

Figure 2-3.30: Percent of Quad bike rollover related ED presentations by departure status, PHREDSS 2006 to 2012



Information on the identification of injuries sustained by individuals in Quad bike incidents were identified through keyword searches for common types of injuries in a provisional diagnosis classification narrative text field. Keyword searches identified 172 (25.4%) fractures, 49 (7.2%) lacerations, 31 (4.6%) open wounds, 27 (4.0%) contusions, 13 (1.9%) dislocations, 10 (1.5%) superficial injuries, and 11 (1.6%) head injuries.

The activity that the individual was performing at the time of the Quad bike incident was not usually recorded in the narrative text fields (n=41; 6.1%). Where activity information was provided, the individual was identified as riding the Quad bike for recreation on the beach or sand dunes (n=16; 2.4%), at an unspecified location that might have included going over jumps (n=3; 0.4%), or at a motor cross event or on a trail (n=3; 0.4%). In the remaining incidents the individual was identified as using the Quad bike for work, such as mustering or spraying (n=10; 1.5%), other and unspecified work (n=7; 1.0%), or travel for work purposes on a rural property (n=2; 0.3%).

Where the narrative text specified descriptive information regarding features of the incident and/or the individual, it was indicated that 74 (10.9%) individuals were wearing a helmet at the time of the Quad bike rollover incident, although two of these individuals were identified as wearing a bicycle helmet. There were 67 (9.9%) individuals who were identified as not wearing a helmet at the time of the incident and for the remaining 535 (79.0%) individuals helmet use was not specified. There were 13 (1.9%) Quad bike rollover incidents where the individual was identified as a passenger and in the remaining incidents (98.1%) the occupant status was not specified. Alcohol consumption was identified in 11 (1.6%) Quad bike rollover incidents and was not specified for almost all incidents (98.4%). Estimated speed of the Quad bike was specified either in km/h or as an estimated range in the narrative text for 170 (25.1%) incidents (Table 2-3.21).

Table 2-3.21: Number of Quad bike rollover related ED presentations where vehicle speed was indicated, PHREDSS 2006 to 2012

Quad bike estimated speed Km/h[1]	Number
0-10	18
11-20	22
21-30	14
31-40	16
41-50	14
51-60	12
61-100+	13
Not known	12
Estimated range	
Low	39
Moderate/ high	8

[1] Kilometres per hour.

Examples of narrative descriptions available in the PHREDDS for Quad bike rollover incidents are shown below *(note: identifying characteristics and/or vital signs of individuals at the time of presentation have been removed. Common medical abbreviations are pt: patient; loc: loss of consciousness; sob: shortness of breath; #: fracture; RT or R: right; L: left; BIB: Brought in by)*:

Riding quad bike approx 5kph, same tipped over - pt landed on right arm, bike landed on pt. Witnessed by relative who lifted bike off immed. wearing helmet. Deformity to right arm....

Quad bike accident. Going up bank at a crawling pace when quad bike rolled backwards. pt hit back and head as pt fell off backwards. handlebars came over and hit pt in nose. no LOC, no tingling or numbness in limbs Injuries - bruised, swollen and bleeding nose.

Accident on quad bike this afternoon. Went over handle bars and states quad bike landed on top of pt on sustaining injury to chest. Chest pain sternal region .... No SOB. Also has muffler burn to left wrist.

BIB helicopter retrieval after accident in remote area. Riding quad bike that rolled over onto pt. Nil LOC...

BIB chopper- was riding quad bike in field when hit a ditch. pt flew over handle bars and quad bike rolled onto pt abdomen ..... Pain and some superficial abrasions.

BIB ambulance post quad bike flipping and falling onto lower legs. pt wasn't wearing a helmet, low speed up and incline when bike flipped. pt states nil LOC, denies neck, back abdominal and pelvic pain. left leg laceration ? #, right leg laceration approx15cm in length...

BIB ambulance quad bike accident. Rolled bike, spraying with round up. Found by relative after 6 hrs lying prone under bike. ? # pelvis. burns to lower leg. ? spinal injuries.

BIB ambulance riding quad bike unsure of speed. Not wearing helmet going down hill bike rolled. Rolled on top of pt injuring r leg and r forearm also side rib pain. Nil LOC.

BIB helicopter post quad bike rolled onto pt at low speed. Injuries to pelvic region...

Came off quad bike today ejected and quad bike rolled over pt. Pushed off by friend. Wearing helmet, same smashed. States was travelling 35-40km/hr..... Nil LOC.

Face trauma..... history was doing weed spraying on property using a quad bike going up hill. the front of the bike came up and overturned landing struck pt face. Pt L arm was trapped for approx 1 hr, nil LOC . laceration at corner left mouth, broken and dislodged teeth-upper right and lower left.

Quad bike with water tank on the back of it- was on private property, riding on the side of a small gully, fell off, landing on right scapula area. Bike then fell on top of pt, states the whole weight of the water tank was on pt. Pt got out from under bike, rode bike back to house.

Rolled quad bike holding 80kg container, pt pinned between same for multiple hours. self extracted and rested against tree as unable to move leg, found by family after 6 hrs. pt complaining of lumber pain, right flank/abdominal pain.

Small non-adult Quad bikes

There were 40 small non-adult Quad bike (note: some of these were 'electric quads', child petrol '50cc Quad bikes', some were 'toy quads' and some were apparently 'youth model' Quad bikes) incidents identified in PHREDSS. For the 40 individuals that presented to an ED following a small non-adult Quad bike incident, there were on average 7 ED presentations each year. There were 21 (52.5%) males and 19 (47.5%) females that presented to an ED for a small non-adult Quad bike related injury. The 5-9 (40.0%) year old and the 0-4 year old (30.0%) age groups had the highest proportion of small non-adult Quad bike related ED presentations. There were 7 (17.5%) ED presentations of teenagers, with the remaining 5 (12.5%) presentations of adults. All of the ED presentations were identified as emergency presentations. The majority of individuals arrived at the ED via the private vehicle (85.0%), with the remaining 6 individuals arriving by the NSW ambulance service or unspecified modes. The majority (80.0%) of individuals were treated and departed the ED, with the remaining 8 (20.0%) either being admitted, departed to another hospital or departed did not wait/ left at their own risk.

Where the narrative text specified descriptive information regarding features of the incident and/or the individual, it was indicated that 12 (30.0%) individuals were wearing a helmet at the time of the small non-adult Quad bike incident. There were 3 (7.5%) individuals who were identified as not wearing a helmet at the time of the incident and for the remaining 25 (62.5%) individuals helmet use was not specified. Twenty (50.0%) of the small non-adult Quad bike incidents involve the individual falling or jumping off the Quad bike and 8 (20.0%) of the small non-adult Quad bike incidents were identified as Quad bike rollovers. Where specified (32.5%), the estimated speed of the small non-adult Quad bike was specified as less than 20 km/h or low.

Examples of narrative descriptions available in the PHREDDS for small non-adult Quad bike incidents are shown below *(note: identifying characteristics and/or vital signs of individuals at the time of presentation have been removed. Common medical abbreviations are pt: patient; loc: loss of consciousness; sob: shortness of breath; #: fracture; RT or R: right; L: left; BIB: Brought in by)*:

> *Riding kids quad bike and crashed into steel fence at 15-20kph large laceration to forehead, abrasion and swelling to (L) side mouth, broken tooth, small abrasion to (L) knee but unable to weight bear on (L) leg. Nil LOC, was wearing helmet.*

> *Child presents post accident/ fall from 50cc quad bike, child was @ the top of a hill, gradient 45 degree slope, child had tried to engage brakes but quad bike was unable to stop, brakes malfunctioned & bike gathered speed going backwards down hill, bike turned & because of speed & momentum handle bars turned suddenly and pt fell backwards off quad bike, and handle bar, circular end hit pt in middle/ L side of forehead, pt's helmet was pushed backwards on head, and q/bike rolled onto pt..... No LOC.*

> *Was riding mini quad bike, flipped off, ?bike landed on pt R arm. Pain in pt right forearm..... was wearing helmet, nil LOC. nil other pain.*

4. Discussion

This report has provided a snapshot of information available in various data collections that can be used to identify the number and describe the circumstances of Quad bike related incidents in Australia (Table 2-3.22). As the data collections utilised were largely designed for administrative purposes, rather than to inform injury prevention activities, they do not contain detailed information on the nature and circumstances of Quad bike related fatal and non-fatal incidents. Information on the make, model and engine size of the Quad bike was rarely available. Limited information was available on how the incident occurred, particularly the sequence of events leading up to the incident. Limited information was also available on the type and nature of injuries experienced by the individual in some data collections.

Prior research conducted in the US to examine Quad bike related fatalities largely used information available from death certificates, medical examiner records, workers' compensation claims and the US Consumer Product Safety Commission and was not able to report detailed information regarding the incident circumstances [3, 7, 9, 24]. The US research was able to indicate the number of Quad bike related fatalities and describe the age group, gender, employment status, industry, occupation, injured body region (e.g. head, trunk), broad injury mechanism (e.g. overturn, hit stationary object), and indicate the location of the incidents. In some instances, information was available regarding helmet use, Quad bike engine size or consumption of alcohol or drugs by the deceased person [9].

Information is included within this report on some Quad bike related fatal injuries as they were identified in the data collections reviewed, but fatal injuries were not specifically examined. A separate study has been conducted to examine Quad bike related fatalities in Australian using data from the National Coronial Information System (NCIS) and from coronial records and has described the type of injuries sustained, along with the Quad bike crash circumstances [25].

Non-fatal injuries related to Quad bike use have been examined in several studies in the US [6, 8, 10, 26] and in New Zealand [27, 28]. Information on non-fatal injuries in these studies were obtained from trauma registries, the US Consumer Product Safety Commission, and hospital admissions data collections. Information from the US and New Zealand data collections was able to describe the basic demographic characteristics of the injured individual. Again limited information was available in these data collections regarding the circumstances of the incident, but information was available regarding the injuries sustained and their severity and length of stay in hospital. For some data collections, information was recorded on helmet use and whether or not the injured individual was the driver or a passenger on the Quad bike.

It is difficult to compare the snapshot findings of this report with research findings of other studies due to differences in the population examined, injury severity and the type and depth of information available in each study. However, information on gender and the type and bodily location of injury following an Quad bike crash for the current snapshot and for previous research was able to be compared. Overall, males were generally more likely to be injured than females in an Quad bike crash in all population-based studies [3, 7-11, 13, 24, 26-28].

In the current snapshot, the most common body location of injuries were the trunk and the upper or lower limbs for Quad bike injuries that resulted in a workers' compensation claim, while the head, knee and lower leg and thorax were the most common body locations of injury for individuals admitted to hospital following the Quad bike crash. Injuries to the head and/or cervical spine, thorax and extremities were also common for individuals hospitalised following an Quad bike crash in Alberta during May 2004 and August 2009 [10]. Similarly, head injuries were common in North Queensland in a study of Quad bike crashes during March 2004 to June 2007 where an individual was either fatally or non-fatality injured and admitted to one of three hospitals [11]. Likewise, head injuries (29%) were common in Waikato in a study of Quad bike crashes that resulted in hospitalisation during February 2007 to March 2011 [28]. In Victoria during 2002-03 to 2010-11, injuries to the upper extremities (30.8%), head/face/neck (25.2%) and truck (23.1%) were common for individuals hospitalised following a Quad bike crash and injuries to the upper extremities (37.1%), lower extremities (22.8%) and head/face/neck (16.9%) were common for individuals presenting to an ED following a Quad bike crash [13].

A 10-year examination of the US Consumer Product Safety Commission during 2001 to 2010 of Quad bike related injuries involving riders aged 15 years or less identified that the head/face/neck (29%), arm/hand (27%) and the leg/foot (26%) were the most common body parts injured [8]. However, in a US Consumer Product Safety Survey of Quad bike injuries in 1997 [14], the most common body parts injured were reported as arm/shoulder (40%) or leg/foot (25%). The differences in the type of injuries reported in the survey compared to the other studies is likely to be due to the severity of the injury experienced, with the other studies all reporting on injuries severe enough to require hospitalisation.

The data collections examined for this report identified that the most common injuries following an Quad bike crash were sprains and strains, fractures or open wounds. Fractures/dislocations (31%), contusions/abrasions (25%) and lacerations (23%) were also the most common type of injury recorded for Quad bike related injuries from a US Consumer Product Safety Survey in 1997 [14]. Likewise, fractures and soft tissues injuries were common in an examination of Quad bike injuries among New Zealand children aged less than 16 years during 2000 to 2006 [27]. Fractures (28%), contusions/abrasions (27%), lacerations (15%) and sprains/strains (11%) were the most common injuries experienced by Quad bike riders aged 15 years or less during 2001 to 2010 [8]. In Victoria, half (49.5%) of all hospital admissions following a Quad bike crash involved a fracture, with one-quarter of ED presentations each involving dislocations, sprains and strains, or fractures [13].

The comparison of the data available for the current study with previously conducted research studies has identified that there is a need for the collection of standardised information to describe Quad bike incidents across research studies and for the collection of information that will enable the Quad bike crash circumstances to be described in-depth (e.g. type and model of Quad bike, use of Quad bike attachments, type of ground surface, activity performed at crash).

In order to obtain the detailed information necessary to adequately identify the circumstances of Quad bike incidents, it appears that would be necessary to conduct a prospective study of Quad bike crashes as the type of information needed is not routinely collected in administrative data collections. Any prospective study should include at a minimum Quad bike and crash site inspections and, if possible, crash reconstructions or simulations, the collection of information on the nature and type of injuries received, along with information obtained from interviews with the injury person and/or any witnesses. A prospective research study would allow for a detailed case series examination of Quad bike related injuries to be conducted. It would be possible to ascertain which injuries followed what type of crash on which Quad bike under what conditions and in what type of environment. Some studies have been conducted that have attempted to examine Quad bike related crashes in-depth, but none have been conducted at a population-level and have combined the analysis of the crash site, the type of model of Quad bike and crash circumstances, combined with the injuries experienced.

Table 2-3.22: Summary of all-terrain vehicle related incidents for the six data collections examined

Data collection	Timeframe	Number of Quad bike incidents	Most common injuries	Most common body location of injury	Quad bike incident	Other comments
SafeWork Australia National Dataset for Compensation-based statistics	1 July 2006 - 30 June 2011 (data provided for different timeframes from each jurisdiction)	n=208 claims, including 2 fatalities	• Sprains & strains (35.6%) • Fractures (29.8%)	• Trunk (29.3%) • Upper limbs (27.4%) • Lower limbs (25.0%)	-	• Workers' compensation claims only • Excludes NSW and Tasmania • Not all injured workers make claims
WorkCover NSW Workers' Compensation Scheme Claims	1 Sept 2003 - 1 July 2011	n=232 claims, including 3 fatalities	• Sprains & strains (41.8%) • Fractures (22.4%)	• Upper limbs (27.2%) • Trunk (24.1%) • Lower limbs (19.4%)	• Fell off Quad bike (25.0%) • Quad bike rollover (22.0%)	• Workers' compensation claims only • Not all injured workers make claims • Identification of cases by Quad bike classification and text descriptions
WorkCover NSW Incident Data	1 Sept 2003 - 3 Nov 2012	n=80, including 17 fatalities	-	-	• Quad bike rollover (40.0%) • Hit object (23.8%) • Fell off Quad bike (13.8%)	• Not all Quad bike incidents notified • Identification by searching text descriptions
Road Crash Analysis System	1 Jan 2006 - 16 Oct 2012	N=12 fatalities	-	-	• Quad bike rollover (58.3%)	• Not all Quad bike incidents captured.
NSW Admitted Patient Data Collection	1 July 2000 - 30 June 2011	n=1,515, including 4 fatalities	• Fractures (47.6%) • Open wounds (13.3%)	• Head (19.5%) • Knee & lower leg (15.1%)	-	• Data quality issues with identification, likely under

Data collection	Timeframe	Number of Quad bike incidents	Most common injuries	Most common body location of injury	Quad bike incident	Other comments
			• Internal organs (8.7%)	• Thorax (13.2%)		enumeration
NSW Near Real-time Emergency Department Data Collection	1 Jan 2006 - 31 Dec 2012	n=3,300 Quad bikes, n=40 small non-adult Quad bikes, and 11 side by side vehicles	• Fractures • Lacerations • Open wounds	-	-	• Possible not all Quad bike incidents identified • Identification by searching text descriptions

4.1 Limitations

There are several limitations of the data collections that were examined. In some cases, it was difficult to accurately identify Quad bike incidents, with these incidents only being able to be identify through searches of text descriptions of event circumstances, such as in the incidents identified in WorkCover NSW data collections, or through identification as a sub-category of another classification, such as a sub-category of special all-terrain vehicles within the APDC. There was a general lack of information recorded in the administrative data collections regarding the model and type of Quad bike, whether any ROPS, attachments or loads were affixed to the Quad bike or whether any objects were being towed by the Quad bike. Whether the injured person was the sole operator or a passenger[2] on the Quad bike was difficult to ascertain in some data collections and information as to whether the individual was wearing either a helmet or a restraint (which is not present on any production Quad bike) was not often collected. Where text descriptions were provided, the exact circumstances of the incident in most cases was difficult to identify. For example, a common phrase was 'fell off ATV', but the reason why the person fell off were not often recorded.

It is possible that some double counting of injured individuals occurred during the examination of different data collections for this report. For example, an individual may have been injured at work and admitted to hospital. This individual may have made a workers' compensation claim and would appear in both the workers' compensation claims data and in the hospitalisation data. From the text descriptions examined of the work related Quad bike incidents, it is estimated that 17 workers' compensation claims in NSW were also the subject of WorkCover NSW Inspectors incident reports. There is known under-enumeration of work related injuries in workers' compensation records, with workers who are self-employed, who are contractors, who are without dependents, or young workers known to not make claims [29].

There is a general lack of exposure data available in order to estimate the risk of injury for most injury types. This is also true for risk of injury following Quad bike use. Estimates are available for the number of Quad bikes sold in Australia, but there is no information available on the number of individuals who use Quad bikes or for the number of hours these individuals use a Quad bike, with this information needed in order to calculate person-risk or person-time risk, respectively.

For workers' compensation claims within Safe Work Australia's NDS, not all of the Australian jurisdictions currently provide workers' compensation data in same format using TOOCS version 3 classification framework where Quad bike incidents are able to be identified. For the jurisdictions using TOOCS version 3, each jurisdiction commenced using this framework at a different point in time, so the injury data provided represents different time periods for each jurisdiction.

The Quad bike related injuries in the WorkCover NSW workers' compensation claims and Inspector's incident reports were identified either through the TOOCS classification framework or by searching incident text descriptions for Quad bike incidents. It is possible that some Quad bike incidents were not identified if text descriptions were missing or there were spelling errors. It was not possible to determine the extent of any false negatives as WorkCover NSW performed case identification procedure. It might be expected that for the Inspector's incident reports, there would be more of an opportunity to obtain detailed information regarding the incident, especially in terms of the type and model of Quad bike, any loads being carried or attachments to the Quad bike or use of personal protective equipment, however much of this information remained missing.

Within the hospitalisation data recorded in the APDC, it is possible that there was better identification and/or recording over time of the four-wheeled Quad bike related injury hospitalisations as enhancements were made to the ICD-10-AM classification framework in 2003-04 to identify the number of wheels on the all-terrain vehicle. Unfortunately, during the timeframe examined for this report, 85.9% of special all-terrain vehicle related injury hospitalisations did not indicate the number of wheels on the vehicle. Of the special all-terrain vehicle related vehicle injury hospitalisations, 11.8% were identified as being work related. However, there is known under-enumeration of work related injury cases in hospitalisation data by around one-third [30]. While there is an activity performed at time of incident classification of 'riding an all-terrain vehicle' within ICD-10-AM (i.e. ICD-10-AM: U65.0), the data quality of activity classifications in hospitalisation data are variable, with McKenzie et al [31] identifying 31.9% disagreement between original coders and auditors of the classification of the activity conducted at the time of injury in a stratified random sample of hospitalisation records. For this analysis, where the external cause classification was 'special all-terrain vehicle related', many of the activity classifications were unspecified (57.5%), resulting in this data variable not being a good identifier of Quad bike related hospitalisations.

For the emergency department presentations reported in the PHREDSS, the number of hospitals participating in ED surveillance increased over time from 38 in 2006 to 59 in 2012. It is possible that some Quad bike injuries were not identified if narrative descriptions were missing, relevant information was absent or there was orthographic variation resulting from spelling errors or use of abbreviations. It was not possible to determine if there were any false negatives in the PHREDSS as the NSW Ministry of Health performed the initial text search case identification and due to the sheer number of records, with 12.8 million records recorded during this time period. The amount of information regarding the incident in the free-text nurse triage assessment and free-text presenting problem fields was variable. It is possible that some of the Quad bike incidents identified involved small non-adult Quad bikes or side by side vehicles, but that these vehicle types were unable to be ascertained from the narrative text. The provisional diagnosis classification in PHREDSS was a mixture of nature of injury, body location of injury and injury mechanism, and as such it is possible that some of an individual's injuries were not identified.

5. Conclusion

A number of administrative data collections were examined in NSW and Australia to provide a snapshot of the information currently available to identify the number and describe the nature of injuries experienced and the type of circumstances of Quad bike crashes. While information was readily available to describe the demographic characteristics of the injured individual, the information contained within the data collections was not ideal to describe the model of Quad bike and any attachments, the purpose for which the Quad bike was being used and the circumstances of the crash, including the geographic typology.

An in-depth examination of Quad bike crashes is needed in Australia, with a prospective study of Quad bike crashes likely to be the best option available in order to obtain detailed information regarding the circumstances of the crash.

6. References

1. Concannon, E., Hogan, A., Lowery, A., Ryan, R., Khan, W., and Barry, K., *Spectrum of all-terrain vehicle injuries in adults: A case series and review of the literature.* International Journal of Surgery Case Reports, 2012. 3: p. 222-226.
2. Milosavljevic, S., McBride, D., Bagheri, N., R., V., Carman, A., Rehn, B., and Moore, D., *Factors associated with quad bike loss of control events in agriculture.* International Journal of Industrial Ergonomics, 2011. 41: p. 317-321.
3. Helmkamp, J., Marsh, S., and Aikten, M., *Occupational all-terrain vehicle deaths among workers 18 years and older in the United States, 1992-2007.* Journal of Agricultural Safety and Health, 2011. 17(2): p. 147-155.
4. Australian ATV Distributors, *Australian ATV Distributors position paper*. 2010, Australian ATV Distributors: Brisbane.
5. Carman, A., Gillespie, S., Jones, K., Mackay, J., Wallis, G., and Milosavljevic, S., *All terrain vehicle loss of control events in agriculture: Contribution of pitch, roll and velocity.* Ergonomics, 2010. 53(1): p. 18-29.
6. Bowman, S., Aitken, M., Helmkamp, J., Maham, S., and Graham, C., *Impact of helmets on injuries to riders of all-terrain vehicles.* Injury Prevention, 2009. 15: p. 3-7.
7. Helmkamp, J., Aitken, M., Graham, J., and Campbell, C., *State-specific ATV-related fatality rates: an update in the new millennium.* Public Health Reports, 2012. 127: p. 364-371.
8. Shults, R., West, B., Rudd, R., and Helmkamp, J., *All-terrain vehicle-related nonfatal injuries among young riders in the United States, 2001-2010.* Pediatrics, 2013. 132(2): p. 1-8.
9. Denning, G., Harland, K., Ellis, D., and Jennissen, C., *More fatal all-terrain vehicle crashes occur on the roadway than off: increased risk-taking characterises roadway fatalities.* Injury Prevention, 2013. 19: p. 250-256.
10. Pelletier, J., McKee, J., Ozegovic, D., and Widder, S., *Retrospective review of all-terrain vehicle accidents in Alberta.* Canadian Medical Association Journal, 2012. 55(4): p. 249-253.
11. O'Conner, T., Hanks, H., and Steinhardt, D., *All-terrain vehicle crashes and associated injuries in north Queensland: Findings from the Rural and Remote Road Safety Study.* Australian Journal of Rural Health, 2009. 17: p. 251-256.
12. Herde, E. and Lower, T., *Quad bike related deaths and injuries, Australia 2010. Media Monitors Report*. 2011, Australian Centre for Agricultural Health and Safety: Moree.
13. Clapperton, A., Herde, E., and Lower, T., *Quad bike-related injury in Victoria, Australia.* Medical Journal of Australia, 2013. 199(6): p. 418-422.
14. Rodgers, G. and Adler, P., *Risk factors for all-terrain vehicle injuries: A National case-control study.* American Journal of Epidemiology, 2001. 153(11): p. 1112-1118.
15. National Occupational Health and Safety Commission, *Type of Occurrence Classification System*. 3rd ed. 2004, Canberra: Commonwealth of Australia.
16. National Occupational Health and Safety Commission, *Type of Occurrence Classification System*. Release 2.1 ed. 2002, Sydney: Commonwealth of Australia.
17. Australian Bureau of Statistics, *Australian Standard Classification of Occupations. Catalogue no.1220.0* Second ed. 1997, Canberra: ABS.
18. Australian Bureau of Statistics, *Australian and New Zealand Standard Industry Classification. Catalogue 1292.0*. 1993, Canberra: ABS.
19. Australian Bureau of Statistics, *Australian and New Zealand Standard Classification of Occupations. Catalogue no: 1220.0*. 2009, Australian Bureau of Statistics: Canberra.

20. Centre for Road Safety Transport for NSW, *Road Traffic Crashes in New South Wales. Statistcal statement for the year ended 31 December 2010*. 2011, Centre for Road Safety, Transport for NSW: Sydney.
21. National Centre for Classification in Health, *ICD-10-AM*. Fifth ed. 2006, Sydney: National Centre for Classification in Health.
22. Muscatello, D., Churches, T., Kaldor, J., Zheng, W., Chiu, C., Correll, P., and Jorm, L., *An automated, broad-based, near real-time public health surveillance system using presentations to hospital Emergency Departments in New South Wales, Australia.* BMC Public Health, 2005. 4(141).
23. SAS Institute, *SAS: statistical software, version 9.3*. 2012, SAS Institute: Cary, North Carolina.
24. Helmkamp, J. and Carter, M., *ATV deaths among older adults in West Virginia: Evidence suggesting that "60 is the new 40!".* Southern Medical Journal, 2009. 102(5): p. 465-469.
25. McIntosh, A. and Patton, D., *All terrain vehicle related injuries and injury mechanisms*. 2013, Transport and Road Safety (TARS) Research, University of New South Wales: Kensington.
26. Axelband, J., Stromski, C., McQuay, N., and Heller, M., *Are all-terrain vehicle injuries becoming more severe?* Accident Analysis & Prevention, 2007. 39: p. 213-215.
27. Anson, K., Segedin, E., and Jones, P., *ATV (quad bike) injuries in New Zealand children: their extent and severity.* The New Zealand Medical Journal, 2009. 122(1302): p. 11-28.
28. Wood, A., Duijff, J., and Christey, G., *Quad bike injuries in Waikato, New Zealand: an institutional review from 2007-2011.* Australian and New Zealand Journal of Surgery, in press.
29. Mitchell, R. and Boufous, S., *Self-reported work-related injury and illness in NSW.* Australian & New Zealand Journal of Occupational Health and Safety, 2005. 21(3): p. 229-236.
30. McKenzie, K., Mitchell, R., Scott, D., Harrison, J., and McClure, R., *The reliability of information on work-related injuries available from hospitalisation data in Australia.* Australian and New Zealand Journal of Public Health, 2009. 33(4): p. 332-338.
31. McKenzie, K., Enraght-Moony, E., Waller, G., Walker, S., Harrison, J., and McClure, R., *Causes of injuries resulting in hospitalisation in Australia: assessing coder agreement on external causes.* Injury Prevention, 2009. 15: p. 188-196.

7. Appendix 1 Off-road 2-wheel motorcycle related injury hospitalisations in NSW

There were 20,957 2-wheel motorcycle related injury hospitalisations identified during 1 July 2000 to 30 June 2011 in the APDC that occurred off-road. Of these, 92.4% involved males (n=19,355) and 1,599 (7.6%) incidents involving females, with the gender of three individuals not specified. The mean age of the injured individual was 30.2 years (range: 1-102 years). Just over one-quarter (26.3%) of hospitalisations involved individuals aged less than 20 years (Figure 2-7.1). Of those aged less than 20 years, 3,260 (15.6%) were aged 15-19 years, 1,680 (8.0%) were aged 10-14 years, 520 (2.5%) were aged 5-9 years, and 61 (0.3%) were aged less than 4 years.

The number of 2-wheel motorcycle related incidents identified in the APDC varied by year, with an average of 1,905 hospitalisations per year (Figure 2-7.2). Median length of stay in hospital was one day (range: 1 to 94 days). The majority of individuals who were hospitalised were either discharged (81.3%, n=17,038) or transferred to another facility (18.2%, n=3,829). Eighty-two (0.4%) individuals were indicated to have died with no information on hospital separation status for eight (0.04%) individual.

Figure 2-7.1: Number of 2-wheel motorcycle related injury hospitalisations by age group, NSW APDC, 2000-01 to 2010-11

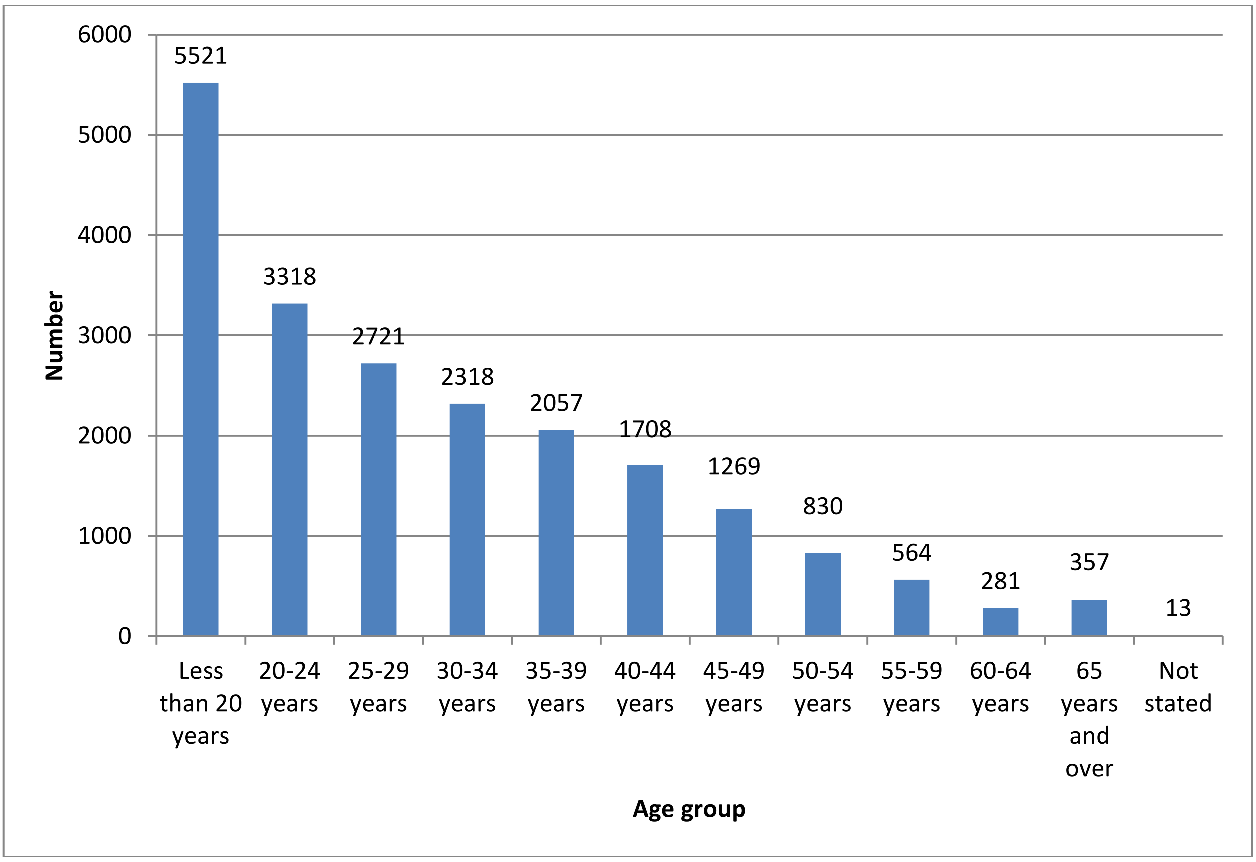
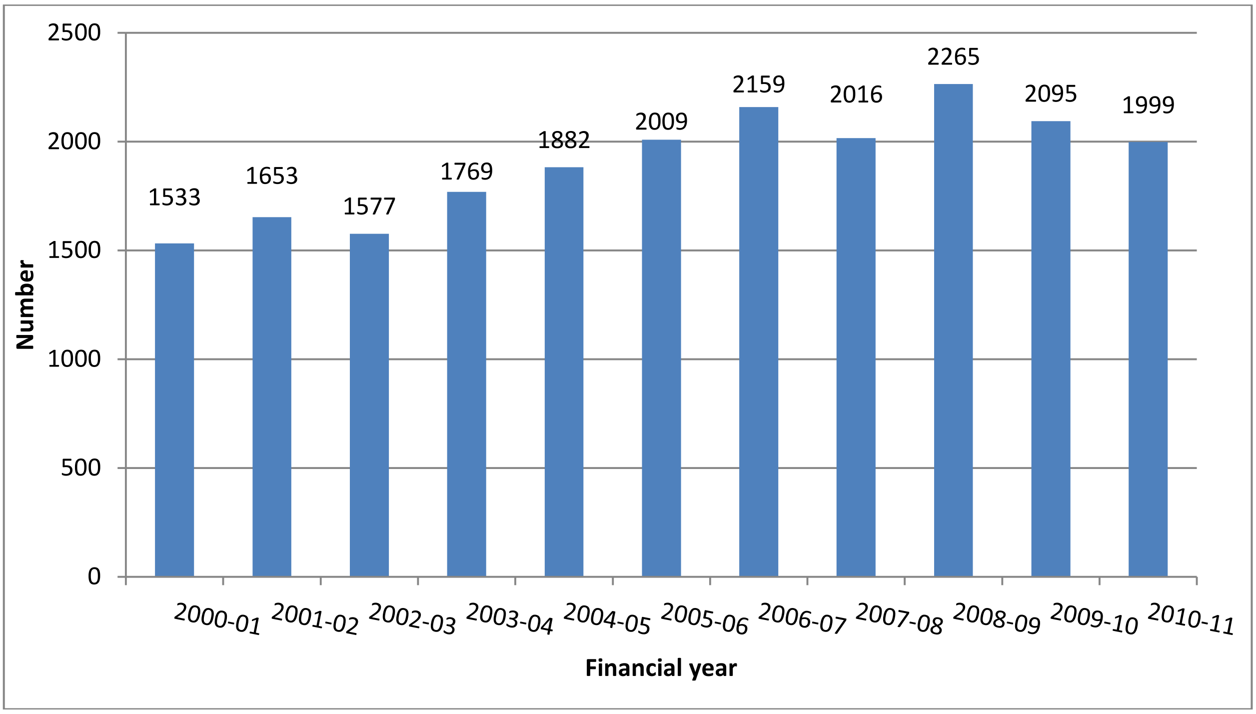


Figure 2-7.2: Number of 2-wheel motorcycle related injury hospitalisations by year, NSW APDC, 2000-01 to 2010-11



The most common principal diagnoses recorded for individuals who were admitted to hospital following a 2-wheel motorcycle related incident were injuries to the knee and lower leg (23.4%), injuries to the shoulder and upper arm (21.1%), and injuries to the head (11.6%) (Figure 2-7.3). Examination of the first 20 injury diagnosis classifications for individuals who were admitted to hospital following a 2-wheel motorcycle related incident showed that the most common injuries were to the knee and lower leg (33.4%) and to the shoulder and upper arm (30.1%) (Figure 2-7.4).

Figure 2-7.3: Proportion of principal diagnosis for 2-wheel motorcycle related injury hospitalisations in NSW by injury type, NSW APDC, 2000-01 to 2010-11

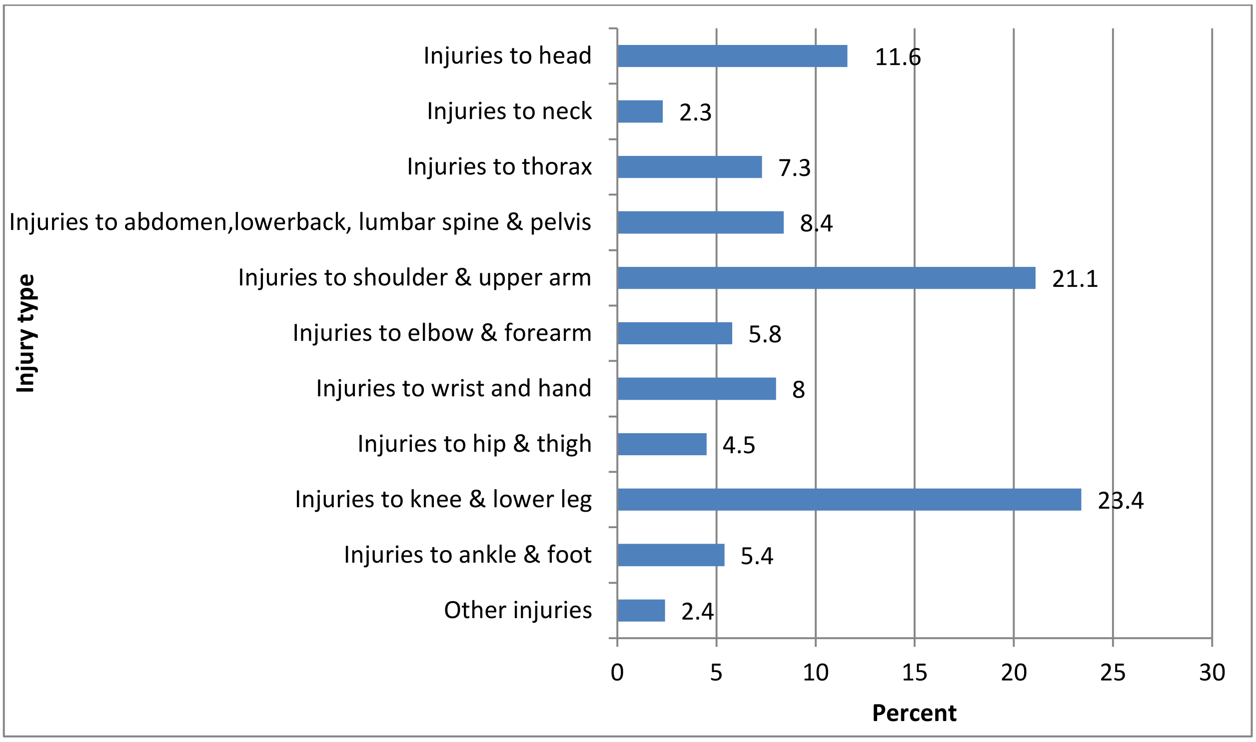
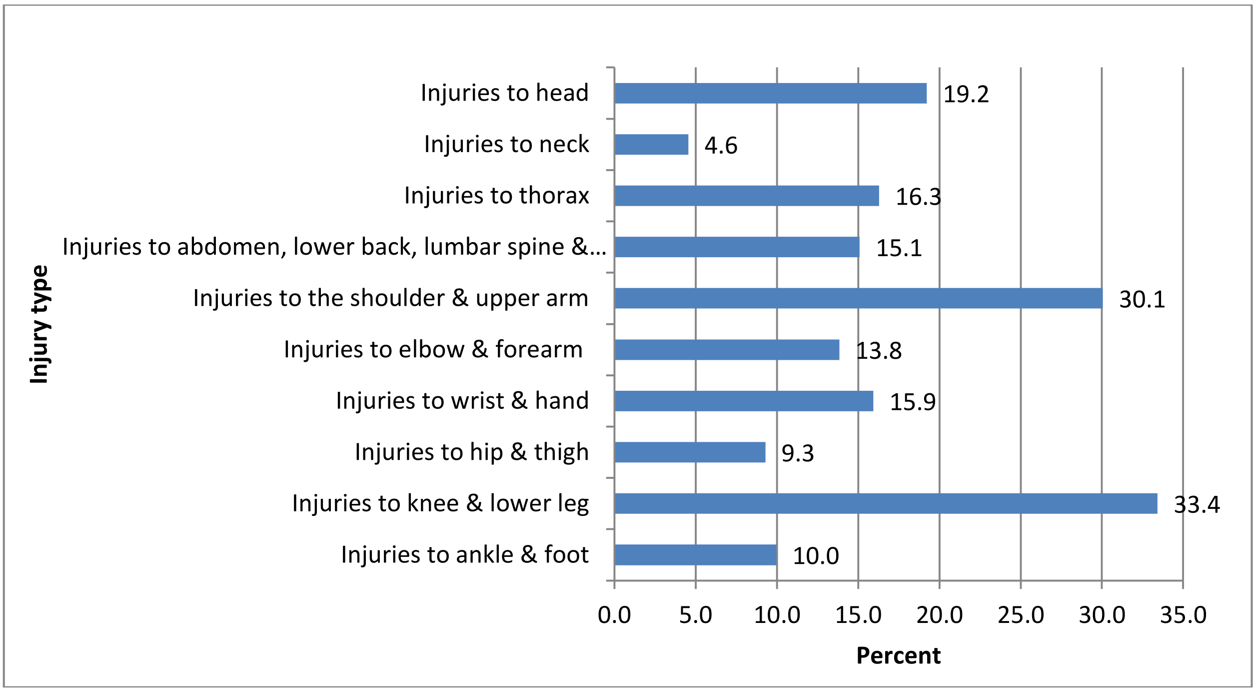


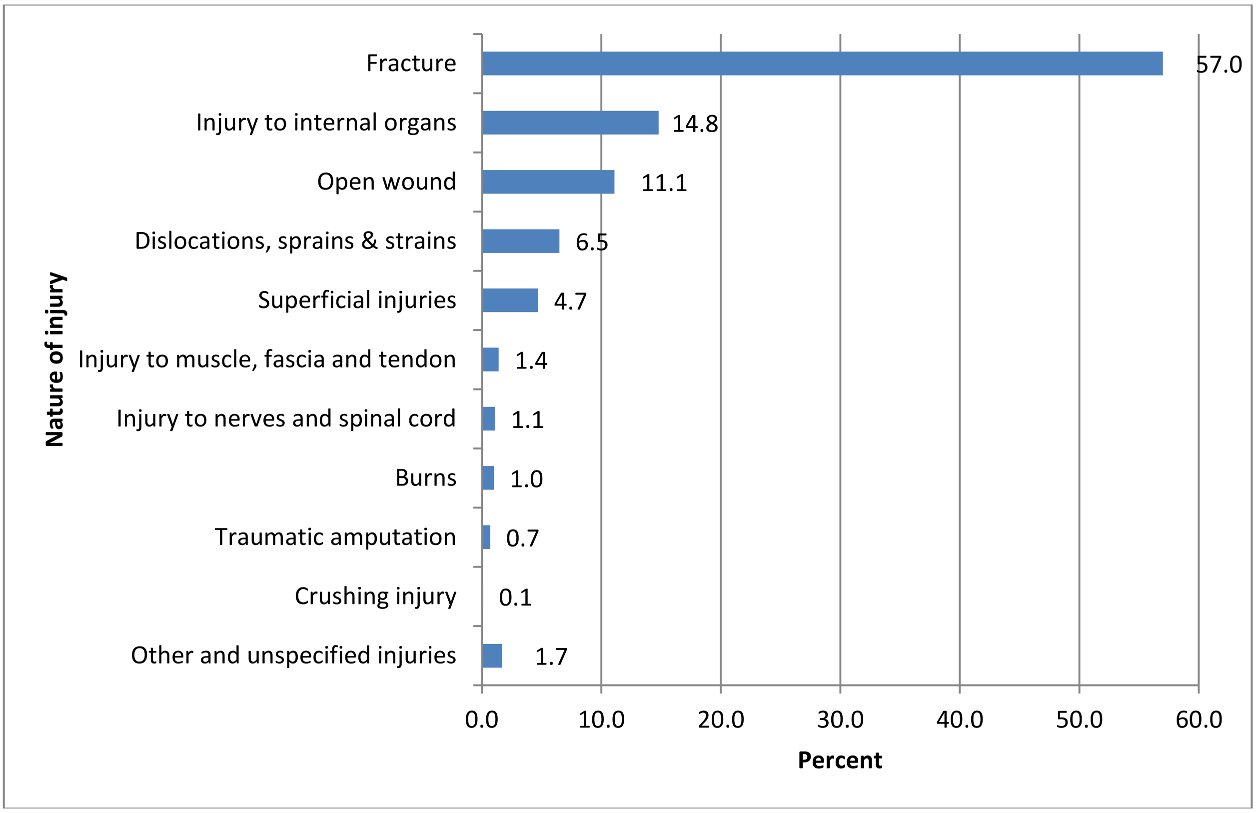
Figure 2-7.4: Proportion of injury diagnoses for the first 20 injury diagnosis classifications for 2-wheel motorcycle related hospitalisations in NSW by injury type[1], NSW APDC, 2000-01 to 2010-11



[1] Includes multiple injuries per person.

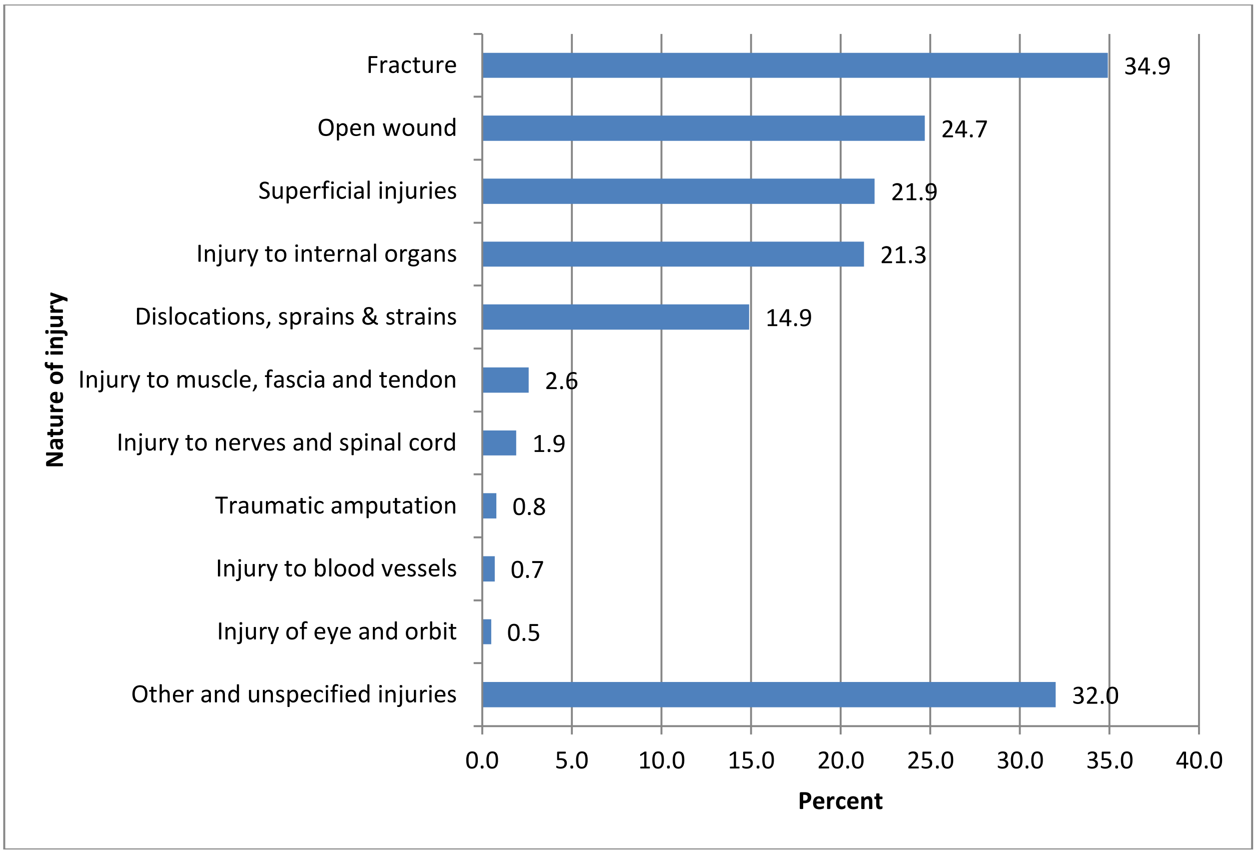
Where the injury was recorded as the principal diagnosis, the most common nature of injury was a fracture (57.0%), injuries to internal organs (14.8%), and open wounds (11.1%) (Figure 2-7.5).

Figure 2-7.5: Proportion of principal diagnosis for 2-wheel motorcycle related injury hospitalisations in NSW by nature of injury, NSW APDC, 2000-01 to 2010-11



Examination of the first 20 injury diagnosis classifications for each of the occupants showed that overall fractures (34.9%) were the most common nature of injury experienced. Open wounds (24.7%), superficial injuries (21.9%), and injury to internal organs (21.3%) (Figure 2-7.6).

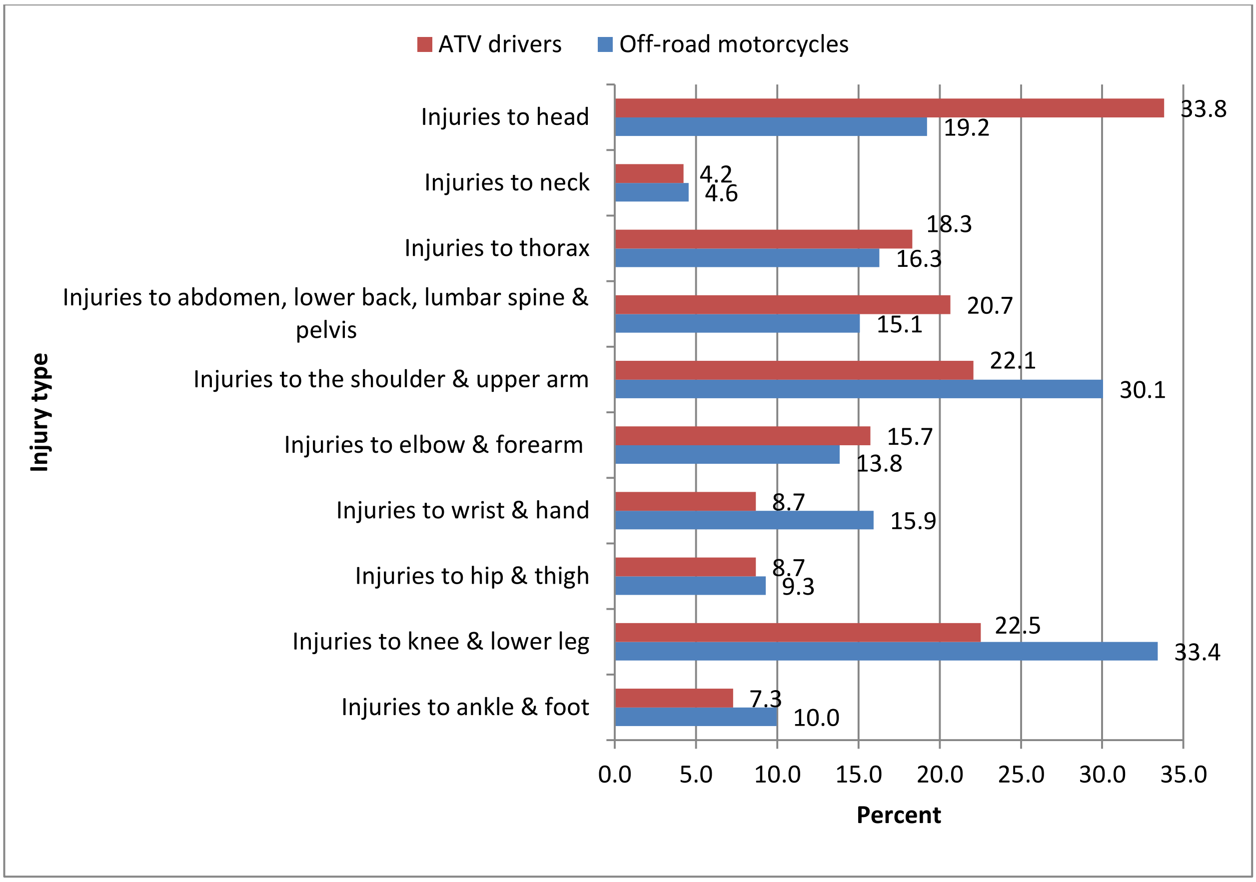
Figure 2-7.6: Proportion of injury diagnoses for the first 20 injury diagnosis for 2-wheel motorcycle related hospitalisations in NSW by nature of injury[1], NSW APDC, 2000-01 to 2010-11



[1] Includes multiple injuries per person.

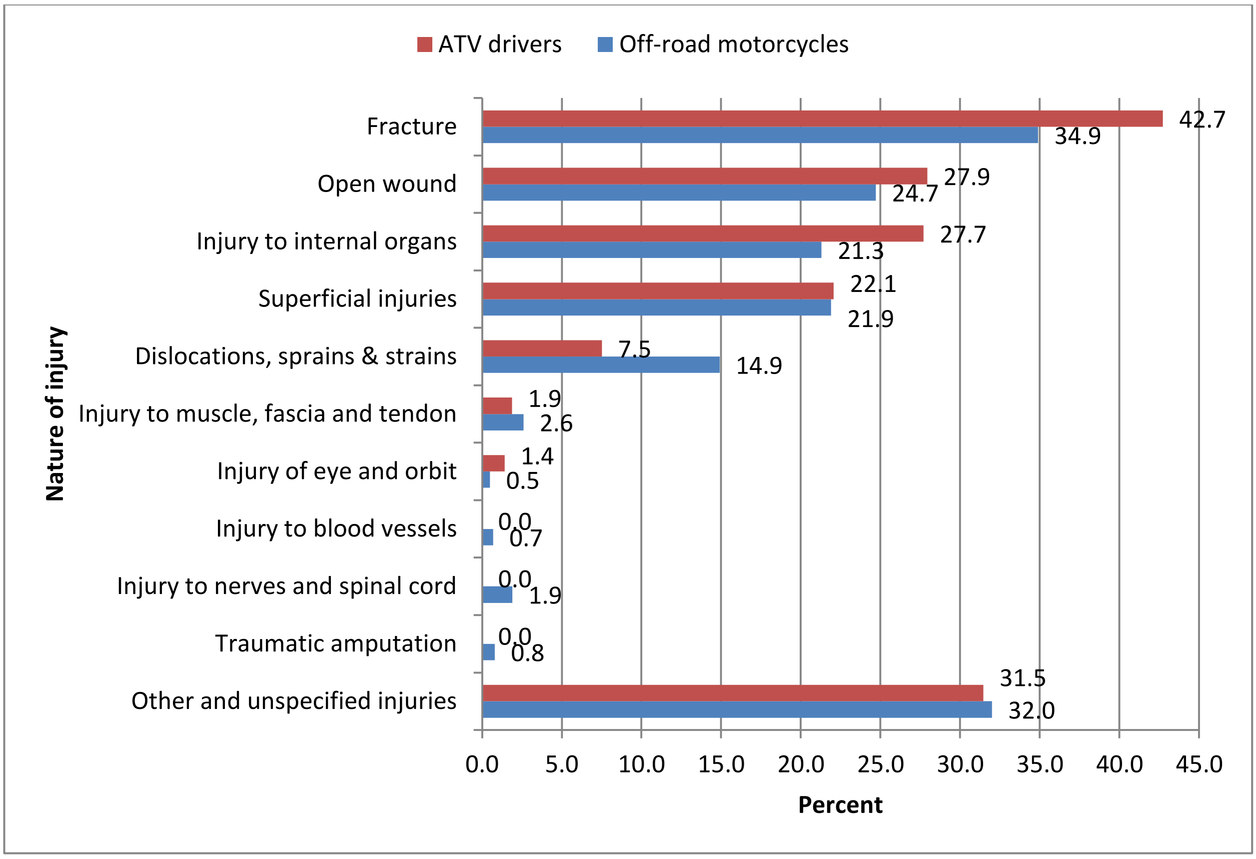
Examination of the first 20 injury diagnosis classifications for special all-terrain vehicle related incidents for drivers only and off-road 2-wheeled motorcycle incidents were conducted. Special all-terrain vehicle drivers more commonly had injuries to the head (33.8%) and abdomen, lower back, lumber spine and pelvis (20.7%) compared to 2-wheel motorcyclists (19.2% and 15.1%, respectively). Two-wheel motorcyclists that were injured in off-road crashes more commonly had injuries to the knee and lower leg (33.4%) and to the shoulder and upper arm (30.1%) compared to special all-terrain vehicle drivers (22.5% and 22.1%, respectively) (Figure 2-7.7). Fractures were the most common nature of injury for both drivers of special all-terrain vehicles (42.7%) and 2-wheel motorcyclists in off-road crashes (34.9%). However, motorcyclists had almost twice the number of dislocations, sprains and strains compared to drivers of special all-terrain vehicles (14.9% versus 7.5%, respectively) (Figure 2-7.8).

Figure 2-7.7: Proportion of injury diagnoses for the first 20 injury diagnosis for special all-terrain vehicle related and 2-wheel motorcycle related hospitalisations in NSW by injury type and occupant[1], NSW APDC, 2000-01 to 2010-11



[1] Includes multiple injuries per person.

Figure 2-7.8: Proportion of injury diagnoses for the first 20 injury diagnosis for special all-terrain vehicle related and 2-wheel motorcycle related hospitalisations in NSW by nature of injury and occupant[1], NSW APDC, 2000-01 to 2010-11



[1] Includes multiple injuries per person.

ATTACHMENT 3: Report on United States Consumer Product Safety Commission (CPSC) Fatal Quad Bike and ATV Crashes: Circumstances and Injury Patterns by Dr. Andrew McIntosh and Dr. Declan Patton.

REPORT 2013

REPORT ON UNITED STATES CONSUMER PRODUCT SAFETY COMMISSION (CPSC) FATAL ATV (QUAD BIKE) CRASHES: CIRCUMSTANCES AND INJURY PATTERNS

By:

Dr Andrew S McIntosh

Dr Declan Patton

Date of Report: 12 December 2013

Executive Summary

The United States Consumer Product Safety Commission (CPSC) is an independent agency of the United States government, which regulates the manufacture and sale of consumer products including all-terrain vehicles (ATVs/ Quad bikes)[1]. The All-Terrain Vehicle Deaths (ATVD) database is the primary database of the CPSC for analyses of ATV-related deaths. It consists of data from investigation and incident reports, which is coded under variables required to generate annual fatality estimates.

A specific case selection protocol was applied to fatal cases from the year 2000. Selection criteria included, for example, a four wheel vehicle, operator, not traffic accident and aged over 16 years. A total of 2718 fatal CPSC cases were selected and analysed. These fatal cases were male (92%) with a median age of 38 years. The majority of vehicles had engine capacities between 200 and 475 cc.

A search of the free text entry in combination with the ATVD coding of the 2718 cases revealed a total of 1951 crashes involved a rollover (72%). In 43% of cases the ATV (Quad bike) landed on the rider. Paved and unpaved roads accounted for the terrain upon which approximately half the incidents occurred. Forests and farmland accounted for approximately one quarter of the incidents by terrain. The activity at time of death, e.g. recreational or farm work, was not documented in the CPSC data set.

The head was the most common body region injured (53%) followed by the upper trunk (17%). Internal injury was the main cause of death and asphyxia occurred in 203 cases (8%). There were very strong significant relationships between a rollover event and both asphyxia and anoxia, and a strong and significant relationship between a rollover event and crushing injury. A rollover was associated with a twelve-fold increase in the likelihood of asphyxia compared to no rollover. A rollover was associated with a twofold increase in the likelihood of crushing injury compared to no rollover. Rollovers were not associated with blunt force trauma or fractures, for example. As per the Australian fatality cases, there is a trend towards rollover crashes causing crushing injuries and, in some cases, asphyxia, and non-rollover crashes resulting in impact related injuries. For example, when the cases were identified in which a collision occurred without a rollover, there was a 150% increase in the likelihood of multiple causes of death compared to the other cases, as well as increases in neck injury and internal injury.

When the CPSC data are interpreted in consideration of the Australian fatal Quad bike crash data, it would appear that there are similar patterns of crashes and injuries. Most important are the two basic observations: rollovers causing crushing injuries and asphyxia; and non-rollover crashes causing head/neck injuries. These two general patterns appear to be consistent with the differences observed generally with Australian fatal cases and between farm work and recreational fatal incidents. The CPSC data and analyses reinforce the findings of the case series analyses of Australian fatal ATV (Quad bike) incidents.

[1] In this report ATV refers only to Quad bikes (not Side by Side Vehicles)

Contents

1 Introduction

The United States Consumer Product Safety Commission (CPSC) is an independent agency of the United States government, which regulates the manufacture and sale of consumer products including all-terrain vehicles (ATVs). The CPSC began its long history with ATVs in the 1980s as a result of the deaths and injuries associated with three-wheeled ATVs.[1] In response to the 1988 lawsuits filed by the CPSC against the five leading manufacturers of three-wheeled ATVs, Final Consent Decrees were established, in which manufacturers agreed not to sell new three-wheel ATVs unless there was a voluntary standard governing their design (which has not been developed since then) and the included provisions regarding age restrictions, instructions, warnings, training and design.[2,3] The consent decrees remained in effect for ten years and after it expired in 1998, the CPSC negotiated Voluntary Action Plans with manufacturers.[4] The Action Plans encompass many of the requirements established by the consent decrees, with some additional and modified requirements.[5]

The All-Terrain Vehicle Deaths (ATVD) database is the primary database of the CPSC for analyses of ATV-related deaths. It consists of data from investigation and incident reports, which is coded under variables required to generate annual fatality estimates.[6] Almost all cases contain a hazard pattern code, which broadly categorises the incident, and a short text summary describing the incident. In Australian, a common Quad bike fatal accident situation in Australia: a single rider over the age of 16 years involved in an off-road single vehicle four-wheeled Quad bike incident.[7]

The aim of this project was to examine the ATVD database in order to understand crash characteristics, injury patterns and injury mechanisms in a population relevant to the Australian context.

2 Methods

2.1 All-Terrain Vehicle Deaths Database

To obtain the ATVD database, a Freedom of Information Act (FOIA) request was submitted to the CPSC. In addition, FOIA requests were also made for the following documents, which were required to explain the coding used in the ATVD database:

- Garland S. All-Terrain Vehicle Deaths Database (ATVD). National Ag Safety Database: Division of Hazard Analysis, U.S. Consumer Product Safety Commission, 2011.

- Ault K.I. Epidemiology Databases: (NEISS, INDP, IPII, DCRT, NFIRS, NCHS) Descriptions, Variables Lists, Codes, by, U.S. Consumer Product Safety Commission, 2001.

2.2 Case Selection Criteria

Cases in the ATVD database was selected only if the selection criteria was satisfied, which required incidents to have:

- occurred during or after the year 2000;
- only involved a four-wheeled ATV;
- not involved passengers;
- involved an operator 16 years or older;
- occurred when the rider was operating the bike;
- been a single vehicle accident;
- not been a traffic incident;
- involved the death of the rider.

2.3 Case Selection

The ATVD database, up until 2010, was obtained, which contained 10383 fatality cases. The presence and detail of the coding, which are outlined by Garland,[6] varied greatly across fields and cases. After the selection criteria were applied to the database, a total of 2718 cases remained (Figure 3-1).

10383 cases

→ Removed cases occurring before the year 2000

6552 cases

→ Removed cases not involving a four-wheeled ATV (Quad bike)

5894 cases

→ Removed cases where a passenger was on ATV (Quad bike)

4268 cases

→ Removed cases with rider under 16 years

3608 cases

→ Removed cases with rider not operating ATV (Quad bike)

3444 cases

→ Removed cases with second vehicle involved in incident

2920 cases

→ Removed cases classed as traffic incidents

2794 cases

→ Removed cases where death occurred to person not operating ATV (Quad bike)

2718 cases

Figure 3-1: Selection criteria and sample size

2.4 Data Coding

After selecting the final case series (n=2718), the data fields and descriptors were examined. Each case included a free text field that contained information on the crash and the injury outcome. In addition to the coded fields in the ATVD dataset, new fields were derived by searching the free text entries for “Hazard Pattern” and “Cause of Death” for key words and using logic functions to establish the descriptor for the UNSW field (Table 3-1, Table 3-2 and Table 3-3). For example, The UNSW field “rollover” was constructed by including all the cases that were classed as positive under the ATVD field “overturn”, had hazard patterns classed as “overturned”, “flipped forward”, “flipped backward” or “rolled sideward”, and returned positive searches of keywords, “ovt”, “ovrt”, “overt” or “roll” , in the hazard pattern summary.

All UNSW fields were dichotomous, e.g. rollover / no rollover or asphyxia / no asphyxia, with the exception of direction. One outcome of the creation of the new fields was the potential for the count of the primary diagnosis to be different to the count of a UNSW field, e.g. fracture. In the free text “imcause”, a case may have involved fracture; however, the diagnosis (“diag”) was crush. Therefore, in that hypothetical case, there would be no change to the total count of crush cases, but an extra fracture case.

The body region coding also permitted a reduction in the number of descriptors, *e.g.* lower extremity included all relevant ATVD “bdpt” fields.

Table 3-1: UNSW field descriptions for crash mechanism

UNSW field	Search codes and terms		
	ATVD field	**Hazard Pattern (hp)**	**Hazard Pattern Summary**
Rollover	ovrturn	overturned, flipped forward, flipped backward, rolled sideward	ovt, ovrt, overt, roll
Direction*		flipped forward, flipped backward, rolled sideward	forward, backward
Slope			slope, steep, hill
Curve			curve
Ejected		thrown, fell or jumped off ATV; thrown off; fell off; jumped off	ej, thrown, fell

Note: * "Direction" only refers to established "Rollover" cases.

2.5 Data Analysis

All data were exported to SPSS version 21. Descriptive analyses were performed. Binary logistic regression analysis was performed to examine the relative differences in injury outcomes (body region and pathology (Table 3-2 and Table 3-3) by crash type.

Table 3-2: UNSW field descriptions for pathology.

UNSW Field	Search	
	Diagnosis of the victim (diag)	**Cause of death (imcause)**
amputation	amputation	
anoxia	anoxia	
aspiration	aspiration	
asphyxia	asphyxia	asphyx
blunt force	blunt force	blunt, force, bf
burn	burn	electrical; not spec.; scald; chemical; thermal
closed	closed	close, chi, cht
concussion	concussion	
contusion	contusion	contus
crush	crush	crush, comp
dislocation	dislocation	disloc
drowning	drowning	drown
exsanguination	exsanguination	exsang, bleed, blood
fracture	fracture	frac, fx, broken
haematoma	haematoma	haema, hema
haemorrhage	haemorrhage	haemorr,hemorr
laceration	laceration	lac
multiple	multiple	mult
open	open	open
pentration	pentration	pene
rupture	rupture	rupt
unknown	unknown	unk

Table 3-3: UNSW field descriptions for body region injured.

UNSW field	Search		
	Injured body part of victim (bdpt)	**Diagnosis of the victim (diag)**	**Cause of death (imcause)**
all	all parts body		
25-50%	25-50% of body		
head/face	head, face, eyeball, mouth, ear	concussion, dental injury	head, hd, face, brain, skull, cranio, cere
neck	neck		neck
spine			spin
thorax	upper trunk, upper trunk (old)		thor, chest, chst
abdomen	lower trunk		abd
internal	internal		int, rupt, organ, lung, pulmo, heart, cardi
nerve		nerve damage	nerve, cord
upper extremities	shoulder, elbow, lower arm, wrist, upper arm, hand, finger		
lower extremities	knee, lower leg, ankle, upper leg, foot, toe		

3 Results

3.1 Demographics

Ninety-two percent of the 2718 fatal cases in the sample were male and the median age was 38 years old (Table 3-4).

Table 3-4: Demographics of case sample

Gender	Age (years)						
	Count	Mean	S. D.	Median	Max.	Min.	Percentage
Male	2496	40	18	38	93	16	91.8%
Female	222	40	16	40	90	16	8.2%
Total	**2718**	**40**	**18**	**38**	**93**	**16**	**100.0%**

3.2 Vehicles

No make and model information is available. The engine capacity was coded in slightly more than half the cases. The majority of known case vehicles were in the range 250 cc to 525 cc (Table 3-5).

Table 3-5: Engine capacity by rollover crash.

Engine Capacity [cc]	Rollover (UNSW field)					
	No rollover		ATV rollover		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Unknown	354	46.2%	869	44.5%	1223	45.0%
< 50	0	0.0%	2	0.1%	2	0.1%
60-90	0	0.0%	2	0.1%	2	0.1%
91-125	2	0.3%	4	0.2%	6	0.2%
126-199	2	0.3%	5	0.3%	7	0.3%
200-224	9	1.2%	21	1.1%	30	1.1%
225-249	8	1.0%	10	0.5%	18	0.7%
250-299	33	4.3%	83	4.3%	116	4.3%
275-324	41	5.3%	111	5.7%	152	5.6%
325-374	54	7.0%	161	8.3%	215	7.9%
375-424	85	11.1%	160	8.2%	245	9.0%
425-474	39	5.1%	113	5.8%	152	5.6%
475-524	46	6.0%	166	8.5%	212	7.8%
525-574	0	0.0%	8	0.4%	8	0.3%
575-624	11	1.4%	13	0.7%	24	0.9%
625-674	37	4.8%	96	4.9%	133	4.9%
675-724	28	3.7%	98	5.0%	126	4.6%
725-774	7	0.9%	16	0.8%	23	0.8%
775-824	8	1.0%	13	0.7%	21	0.8%
> 825	3	0.4%	0	0.0%	3	0.1%
Total	**767**	**100.0%**	**1951**	**100.0%**	**2718**	**100.0%**

3.3.3 Crash characteristics

The hazard pattern as coded in the ATVD dataset identified the two most frequent hazards to be “hit stationary object” 33.7% and “overturned” 31.5% (Table 3-6 and Figure 3-2).

Table 3-6: Hazard pattern as coded in CPSC ATVD.

Hazard Pattern (CPSC)	**Number**	**Percentage**
Unknown	0	0.0%
Overturned	857	31.5%
Flipped Forward	44	1.6%
Flipped Backward	85	3.1%
Rolled Sideward	35	1.3%
Vehicle Encountered Change in Terrain	393	14.5%
Tipped	4	0.1%
Collision	5	0.2%
Collision with Another Vehicle (ATV hit another vehicle)	0	0.0%
Collision with Another Vehicle (Other vehicle hit ATV)	0	0.0%
Hit Stationary Object	916	33.7%
Collision with Person	0	0.0%
Collision with Animal	36	1.3%
Thrown, fell or jumped off ATV	121	4.5%
Thrown Off	139	5.1%
Fell Off	15	0.6%
Jumped Off	5	0.2%
Contact with the ATV itself	1	0.0%
Entrapment	2	0.1%
Contact with Handlebar	3	0.1%
Contact with Wheel	1	0.0%
Contact with Peg	0	0.0%
Contact with Hot Surface	0	0.0%
Contact with Surroundings	16	0.6%
Other Operation	40	1.5%
Non-operating	0	0.0%
Repairing ATV	0	0.0%
Transporting ATV	0	0.0%
Total	2718	100.0%

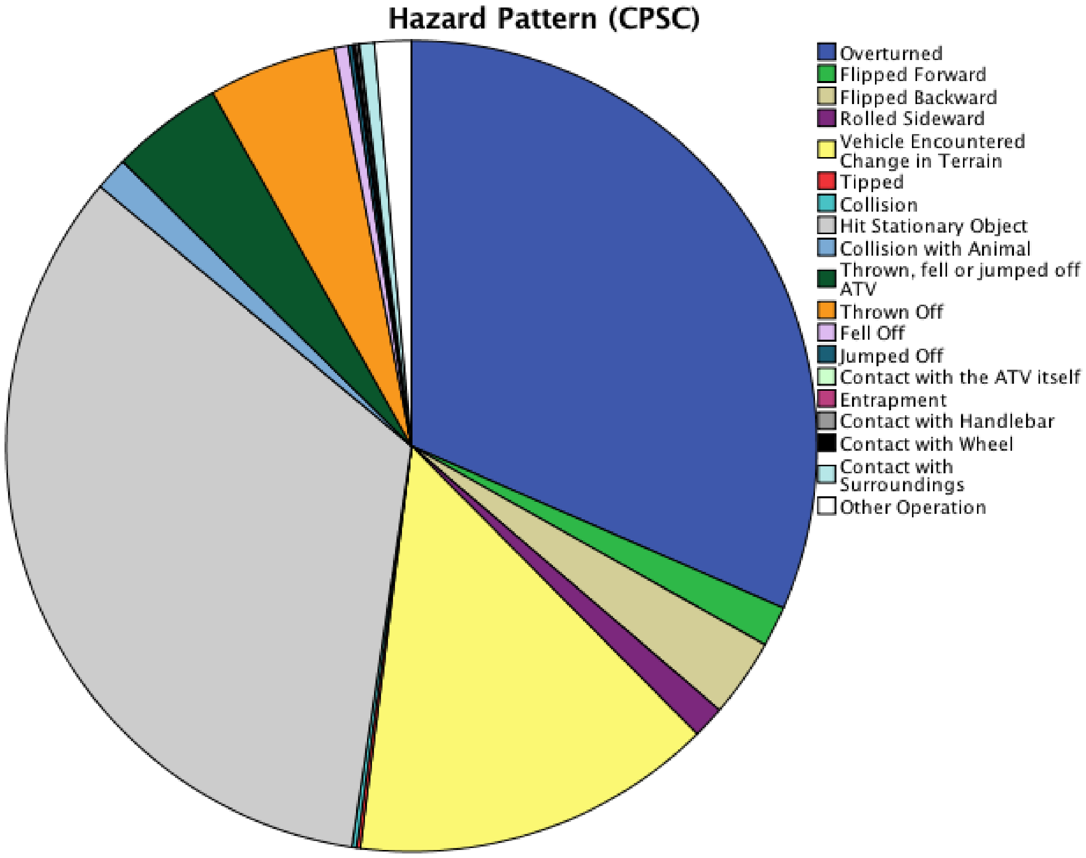


Figure 3-2: CPSC hazard code distribution (n=2718)

Regarding "overturn" crashes, the ATVD coded data identified 517 "no overturns", 273 "unknowns" and 1928 "ATV overturn". Searching the free text entry in combination with the ATVD coding revealed a total of 1951 crashes involved a rollover (72%). **Table 3-7** shows that in many crash types, e.g. "hit stationary object", the ATV (Quad bike) also rolled. The direction of the rollover was unknown in 90.9% of the rollover cases. Where it was known, the majority 4.7% of the rollovers were rearward rollovers. Little was coded regarding whether the crash occurred on a slope.

Regarding the ATV landing on the victim ("atvpers"), in 1157 cases (42.6%) the ATV did land on the victim, in 570 cases this as unknown and in 991 (36.5%) the ATV did not land on the victim. When the free text entry was searched these frequencies were unchanged. Approximately half the fatal cases were ejected (50.5%) and not ejected (49.5%) according to the free text. A helmet was not worn in at least 71.5%, worn in at least 14.3% and unknown in 14.2% of the cases.

Table 3-7: CPSC hazard and rollover crash distributions.

Hazard Pattern (CPSC)	Rollover (UNSW field)			
	No Rollover		ATV Rollover	
	Number	Percentage	Number	Percentage
Unknown	0	0.0%	0	0.0%
Overturned	0	0.0%	857	43.9%
Flipped Forward	0	0.0%	44	2.3%
Flipped Backward	0	0.0%	85	4.4%
Rolled Sideward	0	0.0%	35	1.8%
Vehicle Encountered Change in Terrain	71	9.3%	322	16.5%
Tipped	1	0.1%	3	0.2%
Collision	3	0.4%	2	0.1%
Collision with Another Vehicle (ATV hit another vehicle)	0	0.0%	0	0.0%
Collision with Another Vehicle (Other vehicle hit ATV)	0	0.0%	0	0.0%
Hit Stationary Object	507	66.1%	409	21.0%
Collision with Person	0	0.0%	0	0.0%
Collision with Animal	8	1.0%	28	1.4%
Thrown, fell or jumped off ATV	64	8.3%	57	2.9%
Thrown Off	70	9.1%	69	3.5%
Fell Off	11	1.4%	4	0.2%
Jumped Off	2	0.3%	3	0.2%
Contact with the ATV itself	1	0.1%	0	0.0%
Entrapment	1	0.1%	1	0.1%
Contact with Handlebar	1	0.1%	2	0.1%
Contact with Wheel	0	0.0%	1	0.1%
Contact with Peg	0	0.0%	0	0.0%
Contact with Hot Surface	0	0.0%	0	0.0%
Contact with Surroundings	13	1.7%	3	0.2%
Other Operation	14	1.8%	26	1.3%
Non-operating	0	0.0%	0	0.0%
Repairing ATV	0	0.0%	0	0.0%
Transporting ATV	0	0.0%	0	0.0%
Total	**767**	**100.0%**	**1951**	**100.0%**

The surface or terrain in which the crash occurred was coded (Table 3-8). The single most common surface was paved road (30%). Non-paved road, forest and farmland accounted for a total of 49% of the terrain or surface in which the crash occurred.

Table 3-8: Distribution of crashes by terrain and/or surface

Terrain and surface	Rollover (UNSW field)					
	No rollover		ATV rollover		Total	
	Number	Percentage	Number	Percentage	Number	Percentage
Unknown	23	3.0%	57	2.9%	80	2.9%
Forest	53	6.9%	240	12.3%	293	10.8%
Desert	22	2.9%	41	2.1%	63	2.3%
Off-highway Vehicle Park	12	1.6%	45	2.3%	57	2.1%
Snowboard Trail	4	0.5%	3	0.2%	7	0.3%
Swampland/Marsh	0	0.0%	1	0.1%	1	0.0%
Sand Dunes/Beach	17	2.2%	40	2.1%	57	2.1%
Fields/Pasture/Farmland	59	7.7%	333	17.1%	392	14.4%
Paved Road	296	38.6%	506	25.9%	802	29.5%
Non-paved Road	197	25.7%	450	23.1%	647	23.8%
Snow/Ice	18	2.3%	16	0.8%	34	1.3%
Yard/lawn	13	1.7%	24	1.2%	37	1.4%
Railroad Bed	4	0.5%	14	0.7%	18	0.7%
Storm Drain/Canal	2	0.3%	7	0.4%	9	0.3%
Paved Parking Lot	3	0.4%	12	0.6%	15	0.6%
Other	44	5.7%	162	8.3%	206	7.6%
Total	767	100.0%	1951	100.0%	2718	100.0%

3.3.4 Injury patterns

The most common cause of death was internal injury (51%) followed by crushing (12.5%), fracture (11.1%) and anoxia (6.2%) (Table 3-9). The descriptor "Anoxia" captures cases of asphyxia. CPSC require the use of this field when the patient cannot obtain sufficient oxygen, either due to hampered breathing or lack of oxygen itself. CPSC recommend to code "Anoxia" when the diagnosis is strangulation, suffocation or asphyxia. This is evident in Table 3-10 where the frequencies of asphyxia and anoxia are almost identical.

The most common body region suffering the most severe injury was the head (52.5%) followed by the upper trunk (17.1%), "all parts of the body" (13.7%), the neck (6.6%) and "25-50% of body" (3.4%) (Figure 3-3).

Table 3-9: Cause of death (all cases)

Cause of death	Number	Percentage
Aspiration	2	0.1%
Burn, chemical	1	0.0%
Amputation	1	0.0%
Burns, thermal	4	0.1%
Concussion	45	1.7%
Contusions	17	0.6%
Crushing	339	12.5%
Fracture	303	11.1%
Haematoma	13	0.5%
Laceration	30	1.1%
Nerve Damage	3	0.1%
Internal Injury	1385	51.0%
Puncture	5	0.2%
Anoxia	168	6.2%
Haemorrhage	46	1.7%
Submersion	66	2.4%
Not stated or Unknown	3	0.1%
Other	287	10.6%
Total	**2718**	**100.0%**

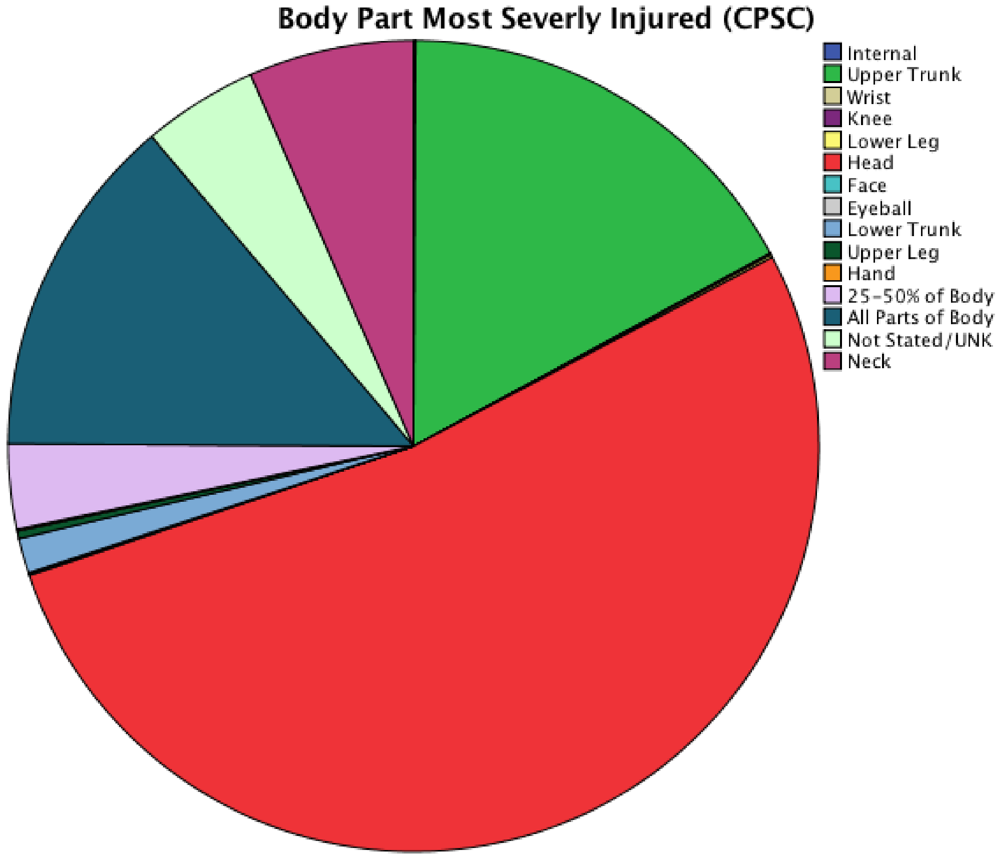


Figure 3-3: Distribution of severe injury by body region.

Table 3-10: Pathology (UNSW field) by rollover (UNSW field).

Injury code (UNSW)		Rollover (UNSW)					
		No rollover		ATV rollover		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
Anoxia	No Anoxia	758	98.8%	1792	91.9%	2550	93.8%
	Anoxia	9	1.2%	159	8.1%	168	6.2%
Asphyxia	No Asphyxia	760	99.1%	1755	90.0%	2515	92.5%
	Asphyxia	7	0.9%	196	10.0%	203	7.5%
Blunt Force	No Blunt Force Trauma	518	67.5%	1367	70.1%	1885	69.4%
	Blunt Force Trauma	249	32.5%	584	29.9%	833	30.6%
Closed	No Closed Injury	733	95.6%	1883	96.5%	2616	96.2%
	Closed Injury	34	4.4%	68	3.5%	102	3.8%
Concussion	No Concussion	751	97.9%	1922	98.5%	2673	98.3%
	Concussion	16	2.1%	29	1.5%	45	1.7%
Contusion	No Contusion	764	99.6%	1943	99.6%	2707	99.6%
	Contusion	3	0.4%	8	0.4%	11	0.4%
Crush	No Crush	698	91.0%	1601	82.1%	2299	84.6%
	Crush	69	9.0%	350	17.9%	419	15.4%
Drowning	No Drowning	742	96.7%	1902	97.5%	2644	97.3%
	Drowned	25	3.3%	49	2.5%	74	2.7%
Exsanguination	No Exsanguination	754	98.3%	1927	98.8%	2681	98.6%
	Exsanguinated	13	1.7%	24	1.2%	37	1.4%
Fracture	No Fracture	651	84.9%	1689	86.6%	2340	86.1%
	Fracture	116	15.1%	262	13.4%	378	13.9%
Haematoma	No Haematoma	680	88.7%	1721	88.2%	2401	88.3%
	Haematoma	87	11.3%	230	11.8%	317	11.7%
Haemorrhage	No Haemorrhage	749	97.7%	1909	97.8%	2658	97.8%
	Haemorrhage	18	2.3%	42	2.2%	60	2.2%
Laceration	No Laceration	740	96.5%	1923	98.6%	2663	98.0%
	Laceration	27	3.5%	28	1.4%	55	2.0%
Multiple	No Multiple Causes	642	83.7%	1686	86.4%	2328	85.7%
	Multiple Causes	125	16.3%	265	13.6%	390	14.3%
Open	No Open Injury	764	99.6%	1947	99.8%	2711	99.7%
	Open Injury	3	0.4%	4	0.2%	7	0.3%
Penetration	No Penetrating Injury	767	100.0%	1949	99.9%	2716	99.9%
	Penetrating Injury	0	0.0%	2	0.1%	2	0.1%
Rupture	No Rupture	763	99.5%	1947	99.8%	2710	99.7%
	Rupture	4	0.5%	4	0.2%	8	0.3%
Unknown	Not Unknown	703	91.7%	1782	91.3%	2485	91.4%
	Unknown	64	8.3%	169	8.7%	233	8.6%

Injury coding was not always informative with regards to the project needs. Therefore, fields were created using the coded ATVD data and the free text. These are presented in Table 3-11. The top five injured body regions are: head/face (56%), internal (53%), thorax (22%), all (14%) and neck (10%). As noted, these categories are not mutually exclusive unlike the ATVD field "body part most severely injured".

Table 3-11: Distribution of injuries by body region

Body region injured (UNSW)		Rollover (UNSW)					
		No rollover		ATV rollover		Total	
		Number	Percentage	Number	Percentage	Number	Percentage
All	Not All	698	91.0%	1647	84.4%	2345	86.3%
	All Body Regions Injured	69	9.0%	304	15.6%	373	13.7%
25-50%	Not 25-50% Injury	736	96.0%	1890	96.9%	2626	96.6%
	25-50% Injury Region	31	4.0%	61	3.1%	92	3.4%
Head/Face	No Head/Face injury	291	37.9%	904	46.3%	1195	44.0%
	Head/Face Injury	476	62.1%	1047	53.7%	1523	56.0%
Neck	No Neck Injury	665	86.7%	1779	91.2%	2444	89.9%
	Neck Injury	102	13.3%	172	8.8%	274	10.1%
Spine	No Spine Injury	757	98.7%	1919	98.4%	2676	98.5%
	Spine Injury	10	1.3%	32	1.6%	42	1.5%
Thorax	No Thorax Injury	616	80.3%	1496	76.7%	2112	77.7%
	Thorax Injury	151	19.7%	455	23.3%	606	22.3%
Abdomen	No Abdominal Injury	744	97.0%	1888	96.8%	2632	96.8%
	Abdominal Injury	23	3.0%	63	3.2%	86	3.2%
Internal	No Internal Injury	337	43.9%	943	48.3%	1280	47.1%
	Internal Injury	430	56.1%	1008	51.7%	1438	52.9%
Nerve	No Nerve Injury	761	99.2%	1944	99.6%	2705	99.5%
	Nerve Injury	6	0.8%	7	0.4%	13	0.5%
Upper Extremity	No Upper Extremity Injury	767	100.0%	1948	99.8%	2715	99.9%
	Upper Extremity Injury	0	0.0%	3	0.2%	3	0.1%
Lower Extremity	No Lower Extremity Injury	761	99.2%	1945	99.7%	2706	99.6%
	Lower Extremity Injury	6	0.8%	6	0.3%	12	0.4%

3.3.5 Relationships between crash characteristics and injury outcomes.

Relationships between crash characteristics and injury outcomes were assessed using binary logistic regression. It must be recognized that all injury outcome variables refer to fatal injuries. Therefore, only the body region or pathology differs, not the actual outcome. There was a twelve-fold increase in the likelihood of asphyxia related to being in a rollover crash compared to a crash without a rollover (Table 3-12). In this case the Hosmer and Lemeshow (HL) test statistic was significant.

Table 3-12: Logistic regression summary for rollover and asphyxia.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
rollover	2.495	.387	41.553	1	.000	12.125	5.678	25.894
Constant	-4.687	.380	152.399	1	.000	.009		

There was also a significant association between rollover and crushing injury, also with significant HL test statistic. Rollover was associated with a two-fold increase in the likelihood of a crush injury (Table 3-13).

Table 3-13: Logistic regression summary for rollover and crushing injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
rollover	.794	.139	32.457	1	.000	2.211	1.683	2.906
Constant	-2.314	.126	336.262	1	.000	.099		

There was a significant association between rollover and anoxia with a seven-fold increase in the likelihood of anoxia if a rollover occurred (Table 3-14). In this case the HL test statistic was significant.

Table 3-14: Logistic regression summary for rollover and anoxia.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
Rollover	2.011	.345	33.914	1	.000	7.473	3.798	14.705
Constant	-4.433	.335	174.824	1	.000	.012		

There was no significant association between rollover and blunt force trauma, multiple causes, haematoma and fracture.

A new binary field "Hit Stationary Object No Rollover" was created for the 916 cases where the ATVD hazard was defined as "Hit Stationary Object"; comprising 507 cases in which no rollover had occurred and 409 in which a rollover had occurred. Associations between this crash descriptor and injury were analysed through logistic regression. As expected inverse relationships to those described above were observed between reduced likelihood of crushing injury, anoxia or asphyxia when no rollover occurred. A positive relationship between multiple causes and "hit stationary object no rollover" was observed, but not for blunt force trauma, haematoma or fracture. A 150% (one and a half-fold) increase in the likelihood of multiple cause death in this type of collision was observed (Table 3-15). In this case the HL test statistic was significant.

Table 3-15: Logistic regression summary for Hit Stationary Object No Rollover (HSONR) and Multiple Cause death.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
HSONR	.419	.130	10.377	1	.001	1.520	1.178	1.961
Constant	-1.874	.063	897.729	1	.000	.154		

Association between rollover and injuries categorized by body region were assessed. There was a significant association between rollover and reduced likelihood of internal injury (16%) and head/facial injury (29%) (Table 3-16 and Table 3-17). There was no association between rollover and abdominal injury, spinal injury and 25-50% body region injury. There was a small significant association between rollover and an increased likelihood of all body region injury (187%) (Table 3-18) and thoracic injury (Table 3-19).

Table 3-16: Logistic regression summary for rollover and internal injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
Rollover	-.177	.086	4.267	1	.039	.838	.708	.991
Constant	.244	.073	11.221	1	.001	1.276		

Table 3-17: Logistic regression summary for rollover and head/face injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
Rollover	-.345	.087	15.686	1	.000	.708	.597	.840
Constant	.492	.074	43.732	1	.000	1.636		

Table 3-18: Logistic regression summary for all body regions.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
Rollover	.624	.141	19.671	1	.000	1.867	1.417	2.461
Constant	-2.314	.126	336.262	1	.000	.099		

Table 3-19: Logistic regression summary for thoracic injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
Rollover	.216	.105	4.188	1	.041	1.241	1.009	1.526
Constant	-1.406	.091	239.725	1	.000	.245		

Association between “hit stationary object no rollover” and injuries categorized by body region were assessed. There was a 150% increase in the likelihood of head/face fatal injury in a hit stationary object no rollover crash compared to all other crashes (Table 3-20) and a similar association for neck injury (Table 3-21). There was a small increase (130%) in the likelihood of internal injury associated with a hit stationary object no rollover crash (Table 3-22). All these relationships were significant.

Table 3-20: Logistic regression summary for Hit Stationary Object No Rollover (HSONR) and head/face injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
HSONR	.424	.102	17.107	1	.000	1.528	1.250	1.868
Constant	.166	.043	15.243	1	.000	1.181		

Table 3-21: Logistic regression summary for Hit Stationary Object No Rollover (HSONR) and neck injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
HSONR	.402	.150	7.166	1	.007	1.495	1.114	2.006
Constant	-2.273	.073	969.292	1	.000	.103		

Table 3-22: Logistic regression summary for Hit Stationary Object No Rollover (HSONR) and internal injury.

Variable	Statistics							
	β	S.E.	Wald	df	Sig.	Exp(β)	95% C.I. for EXP(β)	
							Lower	Upper
HSONR	.251	.100	6.313	1	.012	1.285	1.057	1.563
Constant	.070	.043	2.744	1	.098	1.073		

4 Discussion

A total of 2718 fatal CPSC cases were analysed. These fatal cases were male (92%) with a median age of 38 years, which were consistent with the Australian cases. The majority of vehicles had engine capacities between 200 and 475 cc.

A search the free text entry in combination with the ATVD coding of the 2718 cases revealed a total of 1951 crashes involved a rollover (72%). Even if the crash was coded as hitting a stationary object, the vehicle rolled in many cases. The roll direction was infrequently recorded. In 43% of cases the ATV (Quad bike) landed on the rider. Paved and unpaved roads accounted for the terrain upon which approximately half the incidents occurred. Forests and farmland accounted for approximately one quarter of the incidents by terrain. The activity at time of death, e.g. recreational or farm work, was not documented in the CPSC data set.

The head was the most common body region injured (53%) followed by the upper trunk (17%). Internal injury was the main cause of death and asphyxia occurred in 203 cases (8%). There were very strong significant relationships between a rollover event and both asphyxia and anoxia, and a strong and significant relationship between a rollover event and crushing injury. A rollover was associated with a twelve-fold increase in the likelihood of asphyxia compared to no rollover. A rollover was associated with a twofold increase in the likelihood of crushing injury compared to no rollover. Rollovers were not associated with blunt force trauma or fractures, for example. As per the Australian fatality cases, there is a trend towards rollover crashes causing crushing injuries and, in some cases, asphyxia, and non-rollover crashes resulting in impact related injuries. For example, when the cases were identified in which a collision occurred without a rollover, there was a 150% increase in the likelihood of multiple causes of death compared to the other cases, as well as increases in neck injury and internal injury.

5 Conclusions

When the CPSC data are interpreted in consideration of the Australian fatal Quad bike crash data, it would appear that there are similar patterns of crashes and injuries. Most important are the two basic observations: rollovers causing crushing injuries and asphyxia; and non-rollover crashes causing head/neck injuries. These two general patterns appear to be consistent with the differences observed generally with Australian fatal cases and between farm work and recreational fatal incidents. The CPSC data and analyses reinforce the findings of the case series analyses of Australian fatal Quad bike incidents.

6 References

1. Garland, S., *2011 Annual Report of ATV-Related Deaths and Injuries*. 2013, CPSC: Betheseda, MD, USA.

2. District Court for the District of Columbia, *United States v. American Honda Motor Co., Inc., et al.*, in *Civil Action No. 87-3525*, D.D.C., Editor. 1988.

3. District Court for the District of Columbia, *United States v. Polaris Industries, L.P., et al.*, in *Civil Action No. 87-3525*, D.D.C., Editor. 1988.

4. Kosh, M., *All-Terrain Vehicle - Comment Request - Proposed Resolution*. 1998, CPSC: Bethesda, MD, USA.

5. United States Consumer Product Safety Comission, *ATV Action Plans*. 2008: CPSC.

6. Garland, S., *All-Terrain Vehicle Deaths Database (ATVD)*. 2011, Division of Hazard Analysis, U.S. Consumer Product Safety Comission: National Ag Safety Database.

7. Lower, T., E. Herde, and L.J. Fragar, Quad Bike Deaths in Australia 2001 to 2010. *Journal of Health, Safety and Environment*. 2012;28(1):7-24.

ATTACHMENT 4: Quad Bike Injuries and Fatalities: A Literature review by Dr. Andrew McIntosh and Dr. Declan Patton.

REPORT 2013

QUAD BIKE INJURIES AND FATALITIES: A LITERATURE REVIEW

By:

Dr Andrew S McIntosh

Dr Declan Patton

Date: 12 December 2013

Executive Summary

Quad bike safety has been identified as a major issue on farms in Australia and New Zealand. The Quad Bike Performance Project (QBPP) is fundamentally aimed at improving vehicle rollover stability and crashworthiness. The aim of this report was to identify, obtain and examine the peer-reviewed literature to identify the injured body regions, injury pathology and crash mechanisms for quad bike injuries and fatalities worldwide. A review process, using PubMed, was carried out to identify peer-reviewed articles that investigated fatal and/or non-fatal quad bike incidents. A total of 35 peer-reviewed articles were identified, using the search strategy, and retrieved from the PubMed database.

The literature review identified the main body regions exposed to serious and fatal injuries from quad bike incidents are the head and thorax. Serious and fatal injuries of the spine and abdomen are less frequent. The mechanisms of the injuries are typically impact or crush, in addition to a defined group who are asphyxiated in quad bike crashes. Crash mechanisms are not well described in the literature; however, rollover crashes form a large category of crash types. There are a large range of factors such as speed, intoxication and failure to wear a helmet, which contribute to the crash or the injury outcome.

Contents

1 Introduction

The aim of this report was to identify, obtain and examine the peer-reviewed literature to identify the injured body regions, injury pathology and crash mechanisms for quad bike injuries and fatalities worldwide.

2 Methods

2.1 Search Strategy

A review process, using PubMed, was carried out to identify peer-reviewed articles investigating fatal and/or non-fatal quad bike incidents. PubMed is a free database, maintained by the United States National Library of Medicine at the National Institutes of Health, which primarily accesses citations from the MEDLINE database, in addition to other biomedical literature. The keyword search terms were a Boolean combination of "all terrain vehicle", "all-terrain vehicle", "atv", "quad bike", "quadbike" and "quad-bike". Only English language peer-reviewed journal papers, conference proceedings, theses and books were considered. In addition to the primary PubMed database search, the strategy included a secondary search of the reference lists of identified sources for additional articles, which also satisfied the primary search criteria.

3 Results

A total of 35 peer-reviewed articles were identified, using the search strategy, and retrieved from the PubMed database (Table 4-1).

The source of the data included a large range of geographical regions from national through state to regional or single site. The majority of the studies were retrospective case-series. There were no cohort or randomised control method studies that would provide high quality evidence regarding injury risk factors or the efficacy of interventions, e.g. level one evidence.

Sampling of cases was undertaken using death certificates, trauma centre admissions, Accident and Emergency department admissions, and databases (CPSC, BLS, Department of Labour) populated with specific cases, e.g. fatalities.

The selection criteria varied by injury severity (fatal, admission, injury only) and age. Due to the lack of detail in the data coding the activity undertaken it is difficult to extract meaningful data on work related or agricultural work related crashes and injuries and separate these from recreational or transport crashes.

Table 4-1: Summary of articles identified and retrieved.

Study	Country	State/Region	Duration	Source
DeLisle et al. (1988)	Canada	Quebec	1985	10 regional hospitals
Hargarten et al. (1991)	U.S.	Wisconsin	1983-1989	Death certificate data (ICD-10 codes)
Helmkamp et al. (1999)	U.S.	West Virginia	1985-1997	Consumer Product Safety Commission (CPSC) All-Terrain Vehicle Death (STVD) database
Rodgers et al. (2001)	U.S.	National	1997	Consumer Product Safety Commission (CPSC) National Electronic Injury Surveillance System (NEISS)
Sibley et al. (2002)	Canada	NS	1995-2000	Nova Scotia Trauma Registry (NSTR)
Acosta et al. (2003)	Puerto Rico	National	2000-2002	Puerto Rico Trauma Center
Moroney et al. (2003)*	Ireland	Wexford/ Waterford	1999-2000	Accident and Emergency: Wexford General and Waterford Regional Hospitals
Adams et al. (2004)	U.S.	GA/NC/SC	1988-2002	Medical College of Georgia (level I) Trauma Center
Smith et al. (2005)	U.S.	Houston/ Shreveport	1994-2003	Level I trauma centers: Memorial Hermann Hospital, Louisiana State University Health Sciences Center
Axelband et al. (2007)	U.S.	National	1989-2002	Consumer Product Safety Commission (CPSC) injury data, Pennsylvania Trauma System Foundation (PTSF) database
Balthrop et al. (2007)	U.S.	KY	1998-2003	University of Louisville Trauma Institute database
Bansal et al. (2008)	U.S.	San Diego, CA	2000-2005	University of California San Diego (level I) Trauma Center
Helmkamp et al. (2008)	U.S.	WV	1999-2006	Death certificate data (ICD-10 codes)
Helmkamp et al. (2008)	U.S.	National	2000-2004	Healthcare Cost and Utilization Project (HCUP) State Inpatient Database (SID)
Blackman et al. (2009)	Australia	North Qld	2004-2007	Rural and Remote Road Safety Study (RRRSS)
Bowman et al. (2009)	U.S.	National	2002-2006	National Trauma Data Bank (NTDB)
Hall et al. (2009)	U.S.	WV	2004-2006	Death certificate data (ICD-10 codes)
O'Connor et al. (2009)	Australia	North Qld	2004-2007	Rural and Remote Road Safety Study (RRRSS)
Testerman et al. (2009)	U.S.	TN/VA/KY	2001-2007	Level I trauma center
Thepyasuwan et al. (2009)	U.S.	Bernardino County, CA	2003-2007	Arrowhead Regional Medical Center (ARMC)
Vegeler et al. (2009)	U.S.	IN	1996-2003	Parkview Hospital (level II) Trauma Center
Finn et al. (2010)	U.S.	UT	2001-2005	Trauma centre and hospital databases
Krauss et al. (2010)	Canada	AB	1998-2008	Alberta Trauma Regisrty. Chief Medical Examiner database
Lord et al. (2010)	Canada	ON	1996-2005	Coroner's reports
Müller et al. (2010)	Germany	Hannover	2003-2009	Level I trauma centre. Accident research unit database
Shulruf et al. (2010)	New Zealand	National	2000-2008	New Zealand Department of Labour notifications of serious harm
Winfield et al. (2010)	U.S.	FL	2005-2007	National Trauma Registry of the American College of Surgeons and Shands Hospital discharge database
Bohl *et al.* (2011)	U.S.	National	2007	National Electronic Injury Surveillance System (NEISS)
Helmkamp *et al.* (2011)	U.S.	National	1992-2007	BLS Census of Fatal Occupational Injuries (CFOI)
Merrigan *et al.* (2011)	U.S.	National	2000-2004	National Trauma Data Bank (NTDB)
Alani *et al.* (2012)*	Qatar	Doha	10 months	Hamad General Hospital trauma service

Study	Country	State/Region	Duration	Source
Concannon *et al.* (2012)*	Ireland	Mayo	12 months	Regional hospital case reports
Lower *et al.* (2012)	Australia	National	2001-2010	National Coroner's Information System (NCIS)
Miller *et al.* (2012)	U.S.	WV	1999-2007	West Virginia Trauma Center System Registry
Denning *et al.* (2013)	U.S.	National	1985-2009	Consumer Product Safety Commission (CPSC) All-Terrain Vehicle Death (STVD) database

*Prospective studies

4 Discussion

3.1 Injured Body Regions

Figure 4-1 presents a diagram of injuries by body region showing the collated results of the injury studies. The data indicate that the distributions of injuries by body region for non-fatal and fatal injuries are similar, with the exception of upper and lower extremity injuries. This is typical of injury data distributions by severity and region of injury. The proportion of fatal head or neck injuries is also greater than the proportion of head or neck injuries in non-fatal cases.

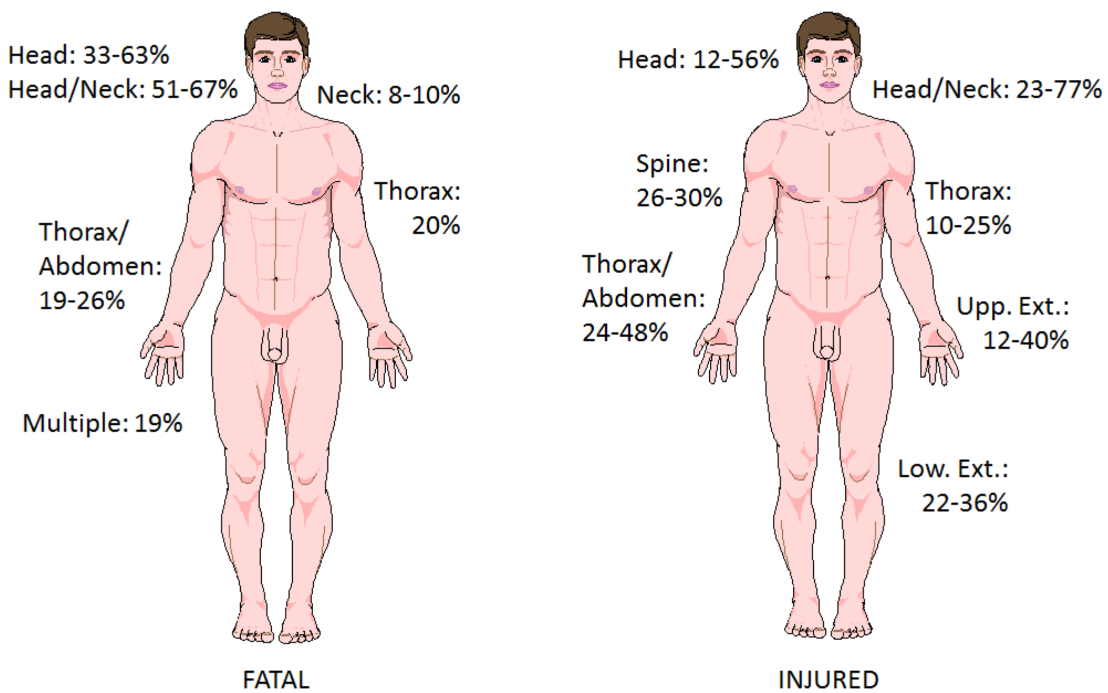


Figure 4-1: Injury distributions by body region.

3.2 Injury Pathology

A variety of common trauma types were described in the literature, which included:

- Blunt force trauma, e.g.
    - Traumatic brain injury (TBI)
    - Fractures
    - Crushing or impact related internal organ injuries (thorax and abdomen)
- Asphyxia

3.2.1 Blunt Force Trauma

Miller *et al.*[1] investigated 1059 quad bike trauma cases and observed a high proportion of head injury (intra-cranial haemorrhage, 19%; skull fracture, 17%; facial fracture,19%), intra-thoracic injury (17%), rib/sternum fractures (17%) and intra-abdominal injury (10%). As expected, based on a substantial body of evidence regarding motorcycle helmet effectiveness, Miller *et al.*[1] also observed significant reductions in head, brain and facial injuries in quad bike riders wearing helmets compared to no helmet. This finding regarding helmets had previously been reported by quad bike investigations during the early 1990s[2,3] and more recently.[4,5] In a study of 58254 hospitalisation cases, Helmkamp *et al.*[6] observed lower extremity fractures to be the most common injury (22%) followed by other fractures (15%) traumatic brain injury (14%), crushing and internal injuries (13%) and upper extremity fractures (12%).

3.2.2 Asphyxia

Asphyxia is not defined or reported uniformly in the literature, which has led to similar research designs having varying results.[7] The term “asphyxia” does not appear uniformly in USA and European reports; however, “crush” injuries have been reported. Lower et al.[8] reported on 112 Australian NCIS fatal cases. In those cases, the primary cause of death by body region was the head (33%), neck (8%), thorax (18%) multiple (17%) and asphyxiation (13%). Fifty-five percent (55%) of rollover deaths involved the thorax, asphyxiation and/or drowning. This data set will be reviewed in detail in this report.

3.3 Crash Mechanisms

The characteristics of the crashes that resulted in the injury or fatal cases are poorly documented. Little is reported on the activity at the time of the crash or the location of the crash. Whether the injury mechanism, e.g. ejection, rather than the crash characteristic, e.g. loss-of-control, is reported is also not always clearly delineated. Rollover is reported as a common crash characteristic,[8-17] which has been found to account for between 14% and 78% of fatal and injury cases, which is a relatively large variation.[9-11,13-15,17] In general the main off-road crash types are rollover and hit stationary object, with contributing factors being the terrain, speed, loss-of-control. Studies have also reported that alcohol and drug use is issue regarding quad bike injuries and fatalities, with 4-50% of victims having some level of alcohol or drugs in their system.[10-15,18-21]

5 Conclusions

The literature review identified the main body regions exposed to serious and fatal injuries from quad bike incidents are the head and thorax. Serious and fatal injuries of the spine and abdomen are less frequent. The mechanisms of the injuries are typically impact or crushing, in addition to a defined group who are asphyxiated in quad bike crashes. Crash mechanisms are not well described in the literature; however, rollover crashes form a large category of crash types. There are a large range of factors such as speed, intoxication and failure to wear a helmet, which contribute to the crash or the injury outcome.

References

1. Miller, M., et al., Injury Prevention and Recreational All-Terrain Vehicle Use: The Impact of Helmet Use in West Virginia. *West Virginia Medical Journal*. 2012;108(3):96.
2. Lehto, M.R. and J.P. Foley, Risk-Taking, Warning Labels, Training, and Regulation: Are They Associated with the Use of Helmets by All-Terrain Vehicle Riders? . *Journal of Safety Research*. 1991;22(4):191-200.
3. Rodgers, G.B., The Effectiveness of Helmets in Reducing All-Terrain Vehicle Injuries and Deaths. *Accident Analysis & Prevention*. 1990;22(1):47-58.
4. Bowman, S.M., et al., Impact of Helmets on Injuries to Riders of All-Terrain Vehicles. *Injury Prevention*. 2009;15(1):3-7.
5. Merrigan, T.L., et al., The Burden of Unhelmeted and Uninsured ATV Drivers and Passengers. *Traffic Injury Prevention*. 2011;12(3):251-255.
6. Helmkamp, J.C., et al., All-Terrain Vehicle-Related Hospitalizations in the United States, 2000-2004. *American Journal of Preventative Medicine*. 2008;34(1):39-45.
7. Sauvageau, A. and E. Boghossian, Classification of Asphyxia: The Need for Standardization. *Journal of Forensic Sciences*. 2010;55(5):1259-1267.
8. Lower, T., E. Herde, and L.J. Fragar, Quad Bike Deaths in Australia 2001 to 2010. *Journal of Health, Safety and Environment*. 2012;28(1):7-24.
9. Balthrop, P.M., et al., Orthopedic Trauma from Recreational All-Terrain Vehicle Use in Central Kentucky: A 6-Year Review. *Journal of Trauma*. 2007;62(5):1163-1170.
10. Hall, A.J., et al., Fatal All-Terrain Vehicle Crashes: Injury Types and Alcohol Use. *American Journal of Preventative Medicine*. 2009;36(4):311-316.
11. Thepyasuwan, N., X.T. Wan, and V.J. Davis, All-Terrain Vehicle Injuries at Arrowhead Regional Medical Center (Level II): Epidemiology, Risks, and Outcome. *American Surgeon*. 2009;75(10):1004-1008.
12. O'Connor, T., H. Hanks, and D. Steinhardt, All-Terrain Vehicle Crashes and Associated Injuries in North Queensland: Findings from the Rural and Remote Road Safety Study. *Australian Journal of Rural Health*. 2009;17(5):251-256.
13. Finn, M.A. and J.D. MacDonald, A Population-Based Study of All-Terrain Vehicle-Related Head and Spinal Injuries. *Neurosurgery*. 2010;67(4):993-997.
14. Krauss, E.M., et al., Ten Years of All-Terrain Vehicle Injury, Mortality, and Healthcare Costs. *Journal of Trauma*. 2010;2010(69):6.
15. Lord, S., C.H. Tator, and S. Wells, Examining Ontario Deaths Due to All-Terrain Vehicles, and Targets for Prevention. *Canadian Journal of Neurological Sciences*. 2010;37(3):343-349.
16. Shulruf, B. and A. Balemi, Risk and Preventive Factors for Fatalities in All-Terrain Vehicle Accidents in New Zealand. *Accident Analysis & Prevention*. 2010;42(2):612-618.

17. Helmkamp, J.C., S.M. Marsh, and M.E. Aitken, Occupational All-Terrain Vehicle Deaths Among Workers 18 Years and Older in the United States, 1992-2007 *Journal of Agricultural Safety and Health*. 2011;17(2):147-155.

18. Testerman, G.M., 300 All-Terrain Vehicle Crashes: An East Tennessee Trauma Center's Experience. *Tennessee Medicine*. 2009;102(8):45-47.

19. Winfield, R.D., et al., All-Terrain Vehicle Safety in Florida: Is Legislation Really the Answer? *American Surgeon*. 2010;76(2):149-153.

20. Bohl, S., M. Sharma, and C. Jones, All-Terrain Vehicle-Related Injuries and Hospitalization: An Examination of the Influence of Age and Alcohol or Drugs. *Open Epidemiology Journal*. 2011;411(123):123-132.

21. Denning, D.A., et al., More Fatal All-Terrain Vehicle Crashes Occur on the Roadway Than Off: Increased Risk-Taking Characterises Roadway Fatalities. *Injury Prevention*. 2013;19(4):250-256.

ATTACHMENT 5: Quad Bike and ATV Crashworthiness Test Protocol by Dr. Andrew McIntosh and Dr. Declan Patton

REPORT 2013

QUAD BIKE and SSV

CRASHWORTHINESS TEST PROTOCOL

By:

Dr Andrew S McIntosh

Dr Declan Patton

Date: 12 December 2013

Table of Contents

Introduction

The methodology that has evolved in the area of biomechanics of injury to develop a test method for assessing injury risks and safety systems involves the following steps:

1. Identification of injury risks
2. Identification of patterns of injuries for specific incidents, e.g. a fall from a bicycle. This takes the form of the distribution of injuries by body region, pathology and severity.
3. Assessment of the gross mechanism of injury for each injury type – region and pathology. For example, the gross mechanism of a cervical spine injury in a fall might be axial compression and neck flexion.
4. Assessment of the local mechanism of injury for each injury type. In the example above, the local mechanism of injury at the site of the injury might be a combination of tensile, shear and compressive strains.
5. Measurement and derivation of human tolerance data for each injury type or a combination of injuries, e.g. thoracic injuries of severity greater AIS $\geq$ 3.
6. The development of a suitable instrument to measure the loads responsible for the injury mechanisms; such as an anthropomorphic test device (ATD) or computer model.
7. Application in a test method or standard of the instrument and injury criteria to assess safety performance and develop new safety systems. An alternative to research and development is for this to be undertaken using computer simulations.

The knowledge and technology that are applied in standard tests evolved over decades. At present there are families of Hybrid III ATDs, side impact ATDs such as Eurosid II and WorldSID, child ATDS, such as the P and Q series, the MATD dummy for motorcycles, and less complex devices such as instrumented rigid headforms used in helmet tests, which are specified in a large proportion of standards or consumer related tests. For many of these devices there are defined injury criteria and injury assessment reference values. ATDs are adapted for novel applications. In this regard the Hybrid III appears to be the most widely used, possibly because of its availability and ruggedness. It has been used in assessing head to head impacts in American football, punches to the head, sideways facing seat tests, and rollover crashes, to highlight some novel applications. None of these devices has been specifically designed for quad bikes.

Fatal injuries related to quad bike (ATV) and Side by Side Vehicle (SSV) crashes include typical impact related injuries, seen in motor vehicle crashes, plus crushing type injuries. The latter injuries include mechanical asphyxia and related conditions. Within many constraints the available ATDs can measure loads associated with typical impact related injuries. However, the ATDs are optimised for a small set of impact scenarios, e.g. frontal and offset frontal impact. No ATD is designed specifically to measure crushing type injuries.

A review and analysis by the authors of published literature, the CPSC database and fatal Australian cases showed that for farm workers typical pattern of severe to fatal injuries is focussed on thoracic injuries, whereas for recreational riders the head is the source of the severe and fatal injuries. There is a small incidence of cervical vertebral and spinal cord injury in both groups. Upper limb and lower limb joint or skeletal injuries are unusual, as are abdominal and pelvic injuries.

The aims of this report are to:

1. Provide a summary of human tolerance data pertinent to quad bike crashes.
2. Identify options and opportunities for measuring biomechanical loads in quad bike crash tests that are relevant to the quad bike operator injury risks
3. Propose injury criteria and injury assessment reference values, and/or other safety criteria that can be applied to assess quad bike operator injury risks in quad bike crash tests.

The focus of the report will be thoracic injury, as these are most relevant to farm workers.

Crashworthy and Safe Design Principles

Some 60 years ago by Hugh de Haven from Cornell University proposed the principles of crashworthy design. These have been compared to the situation of a quad bike in Table 5-1.

Table 5-1: De Haven's crashworthy principles and quad bike characteristics

De Haven	**Quad Bikes (without ROPS)**
I. "The package should not open up and spill its contents and should not collapse under expected conditions of force and thereby expose objects inside it to damage."	The quad bike is open and its contents, the operator, is frequently ejected during a crash. There is no structure to protect the operator, therefore operators are always exposed.
II. "The packaging structures which shield the inner container must not be made of brittle of frail materials; they should resist force by yielding and absorbing energy applied to the outer container so as to cushion and distribute impact forces and thereby protect the inner container."	Quad bike operators are not shielded. There is no structure that can protect the operator.
III. "Articles contained in the package should be held and immobilized inside the outer structure by what packaging engineers call interior packaging."	A quad bike operator is not held or immobilised.
IV. "The means for holding an object inside a shipping container must transmit the forces applied to the container to the strongest parts of the contained object".	There is no means for holding the operator and distributing forces away from the operator.

The workplace safety and ergonomic concept of machine guarding is conceptually relevant to quad bike operators. In a quad bike crash, the kinetic energy and mass of the vehicle are the hazards and machine guarding would be applied to prevent: contact or entanglement with the vehicle (the hazard); the operator being trapped between the vehicle and a fixed structure (pinned on the ground); and, contact between the operator and the vehicle in motion.

Injury Mechanisms

1.1 Summary of NCIS and CPSC Reports

The Report On United States Consumer Product Safety Commission (CPSC) Fatal ATV (Quad bike) Crashes: Circumstances And Injury Patterns presented an analysis of CPSC fatal quad bike crash cases from the USA and a review of the published and grey literature (see Attachment 3). A report on an in depth case series analysis of 109 fatal quad bike and SSV crash cases from Australia was finalised in December 2013 (see Attachment 1). Almost all of the 109 fatalities involved a quad bike.

The analyses revealed a number of key points regarding fatal quad bike crashes:

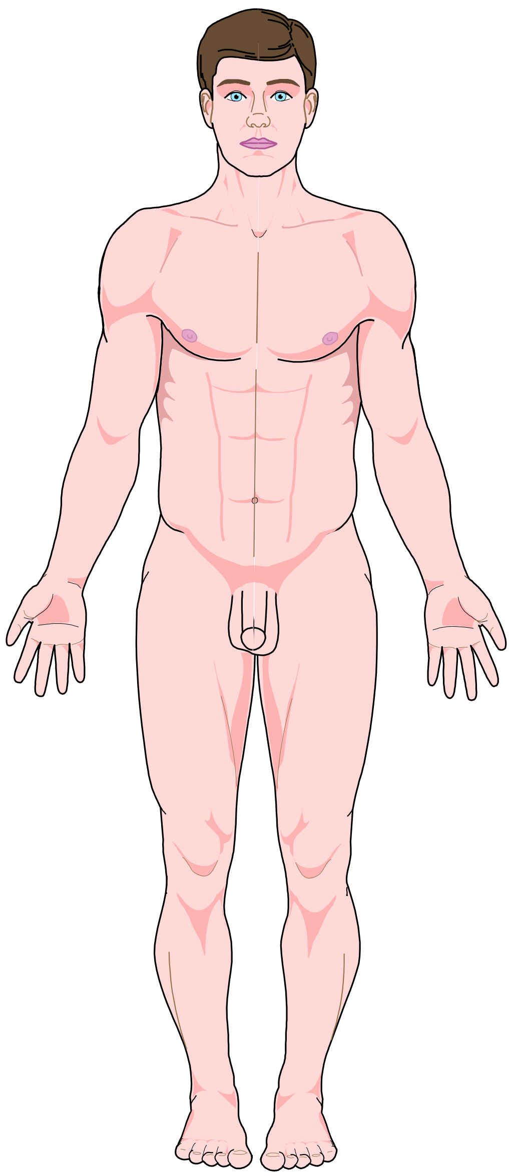
- Regardless of the primary cause of the crash and contributing factors, the majority of crashes involved a rollover;
- Crashes involving rollovers dominated the Australian farm work fatal cases;
- The general impression from crash reports, witness statements and the injury patterns was that fatal recreational quad bike crashes occur at high speed compared to farm cases;
- The general trend in terms of injury profiles was that recreational quad bike operators suffered a higher incidence of severe and fatal head injuries than farm workers, and farm workers suffered a higher incidence of severe and fatal chest injuries, including asphyxia. However, fatally injured recreational quad bike operators suffered a greater proportion of chest injuries than farm workers suffered head injuries. This reinforced the impression that recreational operators were involved in more severe, typically higher speed, crashes than farm workers;
- The strong recommendation by all organisations to increase helmet use for all quad bike operators was reinforced by the analyses. Not only do quad bike operators suffer severe head injuries, there is sufficient evidence to support helmet use to reduce head injury risk. This recommendation needs to be made most strongly in the context of recreational quad bike operation;
- Rollover crashes were strongly associated, and in some statistical analyses significantly associated, with chest injury and asphyxia;
- The primary focus for crashworthiness assessment relevant to farm workers must be thoracic injuries caused by impact forces, crush and/or prolonged static loading on the rider. This focus will address the causes of serious to fatal thoracic injuries (skeletal and organ) and asphyxia during a crash;

- From the perspective of farm workers, a crashworthiness assessment focussed primarily on head and neck injury may not lead to optimal outcomes for thoracic injury prevention. Nonetheless, preventing head and neck injury is important. Consideration will be given for a protocol that permits the assessment of both head and thoracic injury risk;
- There are two main ways in which a quad bike operator can be injured in a crash:
    - Operator-terrain impacts. The operator is ejected and impacts against the local environment. In this situation the velocity and energy of the operator at the point of separation from the quad bike and the characteristics of the object(s) that the operator collides with will determine the injury outcomes; and/or,
    - Quad bike-operator impacts. The quad bike lands on the operator. In this situation the operator will be relatively stationary and the injuries will be determined by the velocity, mass and characteristics of the components of the quad bike that collide with the operator, and how long the weight force of the quad bike is applied to the operator.

1.2 Operator-terrain impacts

Operator-terrain impacts share some characteristics in common with single vehicle two-wheeler crashes. A motorcyclist or bicycle rider may lose control and fall off. The resultant injuries will depend on their velocity, how they fall, what objects are in the environment and the level of protective clothing. As their velocity increases and/or as the environment becomes less forgiving, e.g. a C-section post, the ability of protective clothing to prevent injury will reduce and the injury risks will increase.

Injury mechanisms, i.e. the biomechanical descriptors of the cause of injuries, are presented in Figure 5-1. In brief, for an operator colliding with the terrain the impact forces will produce body segment accelerations and deformations that cause injuries such as intracranial lesions, fractures, organ and vascular injuries. This constellation of injuries was evident in the recreational quad bike fatalities in the NCIS case series analysis.



Head: Impact force leading to linear and angular acceleration, skull deformation, intracranial strain, tensile and shearing of intracranial blood vessels

Cervical Spine: Impact force leading to local bone and connective tissue strains (compression, tensile and shear); loss of space for spinal cord and/or vascular supply disruption.

Thorax: Impact force causing bone and organ compression and viscous loading

Abdomen: Impact force causing organ compression and viscous loading

Pelvis: Impact force causing pelvic bone deformation; largely compression and shear loads

Femur: Impact force causing femur deformation; including compressive, shear and torsional loads.

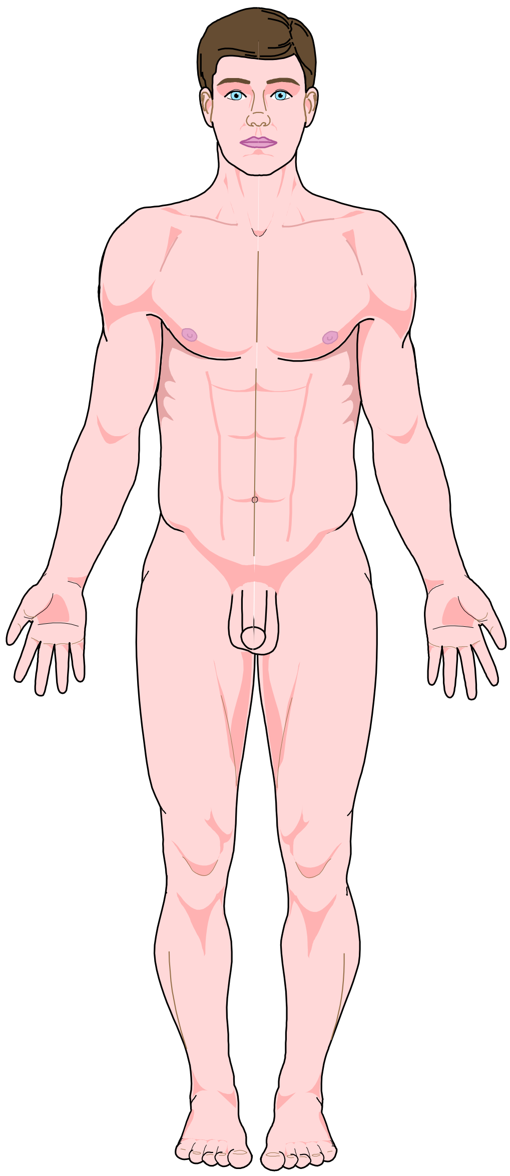
Figure 5-1: Injury mechanisms in operator-terrain impacts.

1.3 QUAD BIKE-OPERATOR IMPACTS

Quad bike-operator impacts are atypical of the majority of transport related impact injuries. Quad bike riders are often impacted by the vehicle and by the ground and environment. Unlike in most transport related collisions, the Quad bike operator will not undergo a substantial velocity change in the impact with the Quad bike and thus the injuries are not due to this type of injury mechanisms, i.e. high decelerations. However, in contrast, the main injury mechanisms for Quad bike operators in the circumstances of being struck by the Quad bike or parts of it, the impact forces are being generated by the rider being subject to 'crush' forces between the Quad bike and ground. This changes the dynamics of the impact, the biomechanical responses of the body segment and the injury outcomes.

If the operator is on the ground and impacted by the quad bike, the accelerations of the operator's head and thorax may be low compared to other impact situations. Therefore, measurement of head acceleration or the Head Injury Criterion may not necessarily capture the true nature of the head loading. Measurements of forces or deformations are a more valid method for determining the likelihood of injury in this situation. Injury mechanisms, i.e. the biomechanical descriptors of the cause of injuries, are presented in Figure 5-2. Many ATDs measure forces and deformations as well as accelerations.

The quad bike may remain on top of the operator causing a proportion of the weight force of the quad bike to be applied to the operator. In these cases the operator is pinned under the quad bike. Except in a few cases the specific part of the vehicle that pinned the deceased operator was not recorded in the NCIS case series. In some cases a broad area of the quad bike was on top of the operator. In a few cases specific components were involved, e.g. in one case the foot rest pinned the operator's neck to the ground in a one quarter roll and caused asphyxiation. The operator's posture varies, from prone to supine to side-lying, therefore a unidirectional thorax may not be appropriate for measuring deflection. Crash dummies are available which can measure lateral as well as fore-aft deflections of the chest/rib cage.



Head: Impact force leading to skull deformation, intracranial strain, tensile and shearing of intracranial blood vessels.

Cervical Spine: Impact force leading to local bone and connective tissue strains (compression, tensile and shear); loss of space for spinal cord and/or vascular supply disruption. Prolonged static loads compromising airways or blood supply.

Thorax: Impact force causing bone and organ compression and viscous loading. Prolonged static loads compromising airways or blood supply.

Abdomen: Impact force causing organ compression and viscous loading.

Pelvis: Impact force causing pelvic bone deformation; largely compression and shear loads.

Femur: Impact force causing femur deformation; including compressive, shear and torsional loads.

Figure 5-2: Injury mechanisms in quad bike operator impacts. The NCIS review identified few pelvic or femoral fractures among farm workers.

Human Tolerance Data

1.4 INJURY CRITERIA

A sample of injury criteria have been tabulated that could be applied to any form of crash or impact test of a component, system or full vehicle (Table 5-2 to Table 5-4). As is shown in Table 5-2 to Table 5-4 the crash test dummy (Anthropomorphic Test Device (ATD)) is specific to the impact direction – frontal or side – and the parameters measured on each ATD differ as do the tolerance levels.

Table 5-2: EuroNCAP tolerance limits – frontal impact

Direction (ATD)	Body region	Situation	Tolerance				
			Level	Parameter	Time [ms]	Limit	Injury
Frontal (Hybrid III)	Head	Airbag	Higher performance	HIC_{36}	36	650	5%≥AIS3
				Acceleration	3	72 g	
			Lower performance	HIC_{36}	36	1000	20%≥AIS3
				Acceleration	3	88 g	
		No airbag (deformable honeycomb faceform test into steering wheel)	Higher performance	Acceleration	Peak	80 g	Not reported
					3	65 g	
			Lower performance	HIC_{36}	36	1000	
				Acceleration	Peak	120 g	
					3	80 g	
	Neck	Cumulative exceedence plots	Higher performance	Shear	0	1.9 kN	Not reported
					25-35	1.2 kN	
					45	1.1 kN	
				Tension	0	2.7 kN	
					35	2.3 kN	
					60	1.1 kN	
				Extension	Not reported	42 Nm	
			Lower performance	Shear	0	3.1 kN	
					25-35	1.5 kN	
					45	1.1 kN	
				Tension	0	3.3 kN	
					35	2.9 kN	
					60	1.1 kN	
				Extension	Not reported	57 Nm	Significant risk of injury
	Chest	Not reported	Higher performance	Compression	N/A	22 mm	5%≥AIS3
				VC	N/A	0.5 m/s	5%≥AIS4
			Lower performance	Compression	N/A	50 mm	50%≥AIS3
				VC	N/A	1.0 m/s	25%≥AIS4

Table 5-3: EuroNCAP tolerance limits – side impact

Direction (ATD)	Body region	Situation	Tolerance				
			Level	**Parameter**	**Time [ms]**	**Limit**	**Level**
Side (ES-2)	Head	Airbag	Not reported	HIC_{36}	36	1000	Not reported
				Acceleration	Peak	80	
		No airbag	Higher performance	HIC_{36}	36	650	5%≥AIS3
				Acceleration	3	72 g	
			Lower performance	HIC_{36}	36	1000	20%≥AIS3
				Acceleration	3	88 g	
	Chest	Not reported	Higher performance	Compression	N/A	22 mm	5%≥AIS3
				VC	N/A	0.32 m/s	5%≥AIS3
			Lower performance	Compression	N/A	50 mm	30%≥AIS3
				VC	N/A	1.0 m/s	50%≥AIS3

Table 5-4: NHTSA tolerance limits

Direction (ATD)	Body region	Situation	Tolerance			
			Parameter	Time [ms]	Limit	Injury
Frontal (Hybrid III)	Head	Airbag	HIC_{15}	15	700	5%≥AIS4
	Neck	Airbag	Nij	N/A	1.0	Not reported
			Tension	N/A	6806 N	
			Compression	N/A	6160 N	
			Flexion	N/A	310 Nm	
			Extension	N/A	135 Nm	
			Tension	N/A	4170 N	
			Compression	N/A	4000 N	
	Chest	Airbag	Acceleration	N/A	60 g	Not reported
			Deflection	N/A	63 mm	
Side (ES-2re/ SID-IIs)	Head	Not reported	HIC_{36}	36	600	25%≥AIS2
					950	25%≥AIS3
					1400	25%≥AIS4
					1050	50%≥AIS2
					1680	50%≥AIS3
					2113	50%≥AIS4
Side (ES-2re)	Chest	Not reported	Compression	N/A	21 mm	25%≥AIS3
					48 mm	25%≥AIS4
					44 mm	50%≥AIS3
					72 mm	50%≥AIS4
			Peak acceleration (lower spine)	N/A	36 g	25%≥AIS3
					70 g	25%≥AIS4
					80 g	50%≥AIS3
					130 g	50%≥AIS4
			Peak acceleration (lower spine)	N/A	15 g	25%≥AIS3
					46 g	25%≥AIS4
					43 g	50%≥AIS3
					74 g	50%≥AIS4
Side (SID-IIs)	Chest	Not reported	Compression	N/A	30.7 mm	25%≥AIS3
					43.2 mm	25%≥AIS4
					37.8 mm	50%≥AIS3
					50.3 mm	50%≥AIS4
			Peak acceleration (lower spine)	N/A	14 g	25%≥AIS3
					65 g	25%≥AIS4
					64 g	50%≥AIS3
					118 g	50%≥AIS4

1.5 Chest Impact Force Criterion

It was recognised that situations arise in which quad bike operators are crushed by the quad bike. Under those situations some of the chest injury criteria presented in section 1.4 may not be relevant. In a laboratory based crash test of quad bike rollovers, an ATD may not be positioned to measure the maximal or relevant loading applied by the quad bike. Therefore, the building blocks for an alternative test approach were examined. That test approach was conceptualised not to use an ATD in a laboratory based rollover test, but to measure the impact force applied by the quad bike to an instrumented floor, the static load and the survival space under the quad bike. This section presents a derivation of a chest injury impact force criterion.

Chest impact force and injury data were extracted from the literature after review of the methods and the data quality. All data pertained to human cadaver experiments, also known as Post Mortem Test Objects (PMTO). In total data from 207 experiments were obtained and collated (Table 5-5). The data were from 70 frontal impacts, 33 lateral chest impacts and 104 lateral shoulder-chest impacts. The ratio of lateral to frontal impacts was two. Impacts were delivered by the cadaver impacting a wall, a pendulum impacting the cadaver or seatbelt loading. It was decided to include all data together as this would provide the greatest distribution of impact force, loading type and injury outcome.

Table 5-5: Sources of PMTO chest impact data

Source	Impacts	
	Number	%
Patrick (1967)	4	1.9%
Fayon (1977,1994)	39	18.8%
Cesari (1981)	15	7.2%
Nusholtz (1983)	25	12.1%
Heidelberg (1986)	13	6.3%
Horsch (1988)	3	1.4%
Viano (1989)	16	7.7%
Cavanaugh (1993)	17	8.2%
Kroell (1994)	36	17.4%
Kuppa (2003)	39	18.8%
Total	207	100%

Descriptive statistics for the forces associated with AIS severity thoracic trauma were derived from the impact type (Table 5-6). The mean peak impact force for thoracic trauma classified as at least "severe" (AIS 4+) was 6035 N compared to thoracic trauma classified as no greater than "serious" (AIS ≤ 3). Here AIS is the Abbreviated Injury Scale and AIS 3 and 4 refer to severity measures. The mean difference is significant ($p<0.05$). Differences were notable for impacts to the front of the chest and the side of the chest, but not when the arm and shoulder were involved (appendix A). There was a substantial distribution in the force and injury data. Therefore, as already known, the involvement of the arm and shoulder are critical in interpreting the outcome of lateral impacts. The arm and shoulder absorb and distribute the loads applied to the thorax.

Table 5-6: Descriptive statistics for chest impact forces by injury severity.

Impact location	Thoracic injury severity					
	AIS serious or less (≤AIS3)			AIS severe or greater (≥AIS4)		
	No.	Peak impact force [N]		No.	Peak impact force [N]	
		Mean	Standard deviation		Mean	Standard deviation
Frontal	48	2504	2691	22	4528	1646
Lateral chest	23	2509	2315	10	6669	3138
Shoulder/chest	65	5052	3745	39	6722	4515
Total	136	3737	3412	71	6035	3766

A Receiver Operator Characteristic (ROC) analysis was undertaken with the data divided into two groups (a) AIS 0:3 and (b) AIS 4:6. A significant relationship was observed with an area of 0.731. In the ROC analysis sensitivity is the proportion of AIS 4:6 cases with force results greater than the cut-off. "1-specificity" is the proportion of AIS 0:3 cases with force results greater than cut-off. For this dataset, if we consider a cut-off (injury threshold) for peak thorax force of 3,500 N for severe and greater thoracic injuries, then 78.9% of all AIS 4:6 injury cases will be correctly identified and 36.8% of AIS 0:3 cases would be incorrectly identified as AIS 4:6 (Table 5-7 and Figure 5-3). This is not an optimal relationship. Ideally, at 3.5kN there would be a greater than 90% correct identification of AIS 4:6 injury and a less than 10% incorrect identification of AIS 4:6 injury. However, it is robust in terms of loading direction, contact potential and injury outcomes.

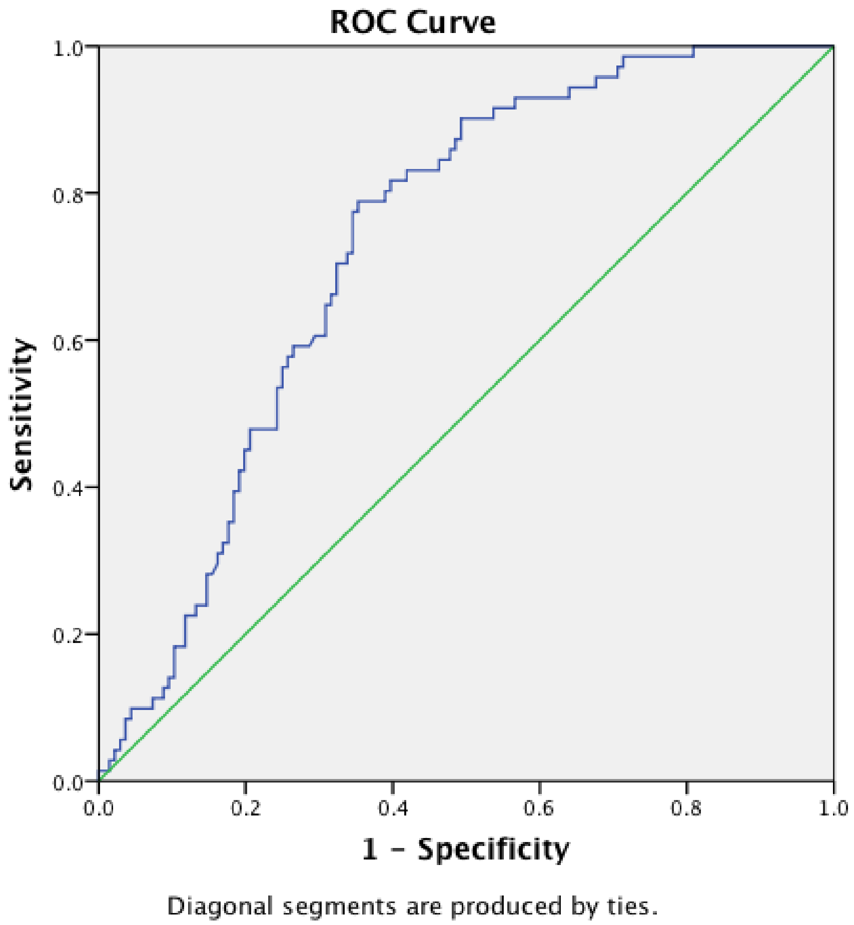


Figure 5-3: ROC curve for impact force vs. AIS 0:3 and AIS 4:6

Table 5-7: Analysis of ROC curve for impact force vs. AIS 0:3 and AIS 4:6

Area	Std. Error (a)	Asymptotic Sig. (b)	Asymptotic 95% Confidence Interval	
			Lower Bound	Upper Bound
.731	.034	.000	.664	.799

The test result variable(s): Peak Impact Force (N) has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased. (a). Under the nonparametric assumption (b). Null hypothesis: true area = 0.5

It is proposed that an injury criterion of 3.5 kN peak impact force is applied to assess thoracic injury potential in quad bike rider rollover safety tests. A discrete rating scale could be developed based on these data.

1.6 MECHANICAL/TRAUMATIC ASPHYXIA

French physician Charles-Prosper Ollivier d'Angers was the first to recognise traumatic asphyxia in 1837 during autopsies of multiple individuals who had been trampled by crowds in Paris.[1] One challenge in the study of traumatic asphyxia is that it has a binary outcome and cannot be investigated fully with volunteers or PMTO.

Bierman *et al.*[2] applied static loads to the anterior chest and abdomen of eight volunteers using a vest-type restraining harness. Volunteers were subjected to loading of 2447 N resulting in an average tolerable duration of 26.4 seconds with one subject tolerating the load for 80 seconds. During the application of static loads, it was observed that thoracic respirations of the subjects diminished or ceased.

Evans *et al.*[3] carried out a series of laboratory experiments to determine the crushing loads that could be passively tolerated by adult volunteers, 32 male and 12 female. For males, it was found that mean loads of 476 N and 623 N were subjectively intolerable after a few seconds pressed against a 1.07 m high crush barrier constructed of steel tube and 100 mm wide wooden plank, respectively. The values for females were found to be approximately one third of the values reported for males.

Field measurements have also been obtained during soccer matches using instrumented barrier rails.[4 5] Loads of 1.5 kN/m to 2.9 kN/m were measured, with occasional peaks of up to 4.4 kN/m; however, the loads did not exceed 2.9 kN/m for more than 3 seconds.

Following the 1971 Ibrox Park stadium disaster, where 66 people died during crowd crush in a stairway, Lord Wheatley conducted an inquiry into safety at sports grounds, which became the foundation report for the 1973 "Green" Guide to Safety at Sports Grounds[6] and the 1975 Safety of Sports Grounds Act.[7] A document by the Home Office,[8] summarising the research commissioned by the Wheatley Inquiry, reported tolerance values of 2481 N/m (1335 N per person) and 1678 N/m (890 N per person) for levels of "safety only" and "safety plus comfort", respectively. Additionally, the report summarised two fatal cases of traumatic asphyxia: 6.23 kN for a duration of 15 seconds and 1.33 kN for a duration of four to six minutes. The second and third editions of the Green Guide contained revisions in response to the 1985 Bradford City stadium fire and the 1989 Hillsborough Stadium disaster, respectively.[6]

Fruin[9] investigated the causes and prevention of crowd disasters and found evidence of bent barrier rails after several fatal crowd incidents have led to force estimates of more than 4.5 kN. Fruin[9] also used Police reports from the Ibrox Park stadium disaster, indicating that the pile of bodies was 3 m high, to estimate chest loading of 3.6 kN to 4.0 kN experienced by people underneath.

Hopkins *et al.*[10] obtained field measurements from a variety of activities where barrier rails were used. During New Year's Eve celebrations, loads of 2 kN/m, 1 kN/m and 0.6 kN/m (1 kN, 0.5 kN and 0.3 kN per person) were recorded for maximum peak, 30 second average and 40 minute average values, respectively. During concerts, loads of 4.2 kN/m, 1.8 kN/m and 1.5 kN/m (2.1 kN, 0.9 kN and 0.75 kN per person) were recorded for maximum peak, 30 second average and 10 minute average values, respectively. Coutie *et al.*[11] instrumented a barrier rail at a soccer ground with a strain gauge and recorded a maximum distributed load of 1.8 kN/m (0.9 kN per person) during a competitive match; however, the time interval was quite short. Hopkins *et al.*[10] also presented speculative tolerance curves for death and loss-of-consciousness (reproduced in Figure 5-4).

Smith *et al.*[12] determined the crushing loads that 21 human subjects, 19 male and 2 female aged from 20 to 25 years, were able to withstand against a barrier rail until they felt "very uncomfortable". Three different sections of barrier rail, steel tubing (diameters of 60 mm and 110 mm) and a flat steel plate (150mm deep), were loaded against the chest, lower chest and abdomen of the subjects. A tolerable load range of 0.75 kN/m to 1.03 kN/m was found for all combinations, barrier rail sections and body regions. The two female subjects withstood loads lower than the average; however, they did not record the lowest tolerable loads. It was suggested that the most likely cause of death experienced by spectators being crushed against a barrier rail is asphyxiation.

Bendjellal *et al.*[13] analysed frontal car collision cases in order to investigate seat belt-induced thoracic injuries and found that a belt load threshold of 6 kN was not sufficient to prevent the risk of serious thorax injury. It was concluded that shoulder belt load should be limited to 4 kN to reduce the risk of thoracic injury, which was subsequently supported by Foret-Bruno *et al.*[14]

McKenzie[15] investigated the practice of "peine forte et dure [hard and forceful punishment]", also known as "the press", which was the torture technique of placing iron or stone weights upon the chest of a prisoner, lying prone on the prison floor, for extended periods of time in order to force them to plead guilty. One prisoner endured 1557 N for approximately half an hour, at which time the weight was increased to 1779 N and the prisoner pleaded guilty; however, another prisoner was subjected to 1779 N and died. Other examples describe prisoners surviving 1112 N and 1677 N for 7 and 63 minutes, respectively.

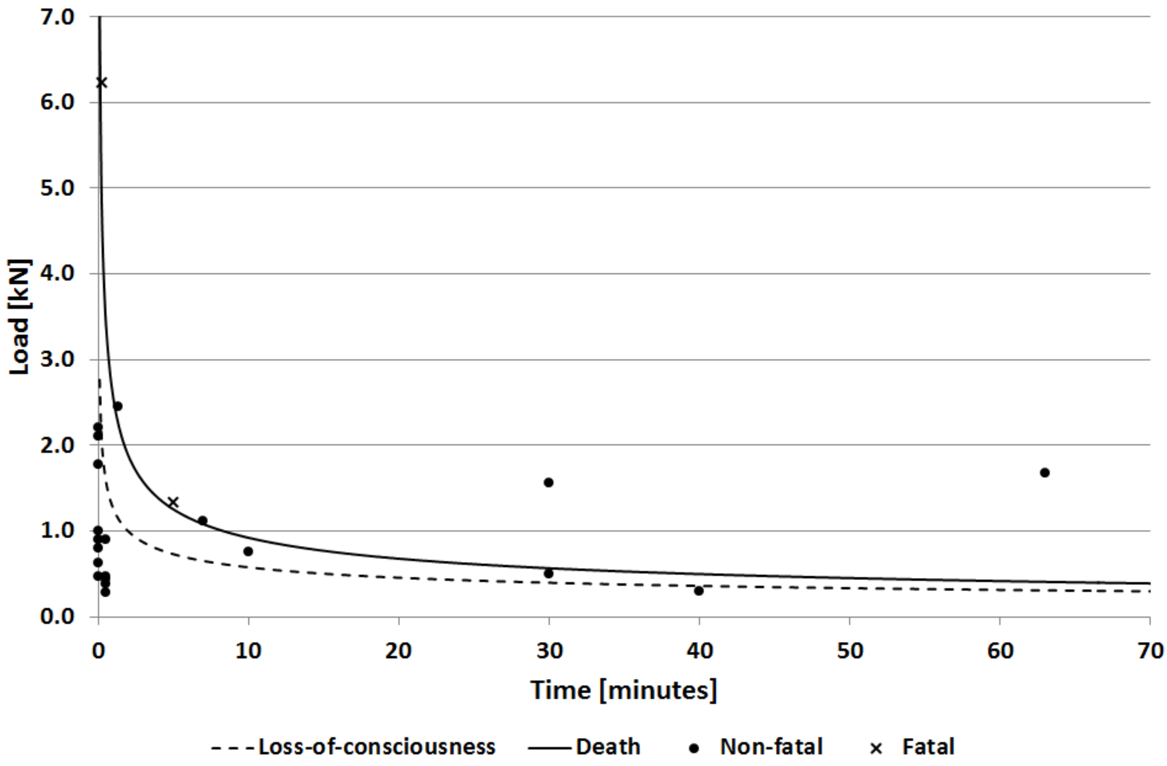


Figure 5-4: Fatal and non-fatal thorax load tolerance data compared against speculative thorax load tolerance curves reproduced from Hopkins *et al.*[10]

It is proposed that a maximum static weight force of 500 N, equivalent to 50 kg, should be permitted in a crashworthiness test. The static load should be measured over a period of five minutes. A scaling system could be interpolated with full score at 0 N and no score at 500 N.

Table 5-8: Thorax load tolerance data from various sources.[2-5 8-12 15]

Source	Method	Subjects	Load [N]	Duration	Outcome
Bierman *et al.* (1946)	Loads passively tolerated by anterior chest and abdomen using a vest-type restraining harness	Adult male volunteers	2447	80 seconds	Non-fatal
Evans *et al.* (1971)	Loads tolerated against a 1.07 m high steel tube (50 mm diameter) with passive resistance	Adult male volunteers	276	30 minutes	Non-fatal
		Adult male volunteers	476	Few seconds	Non-fatal
	Loads tolerated against a 1.07 m high steel tube (50 mm diameter) with active resistance	Adult male volunteers	796	Few seconds	Non-fatal
	Loads tolerated against a 1.07 m high wooden plank (100 mm wide) with passive resistance	Adult male volunteers	623	Few seconds	Non-fatal
Bingham Blades & Partners (1971, 1972)	Distributed loads measured by instrumented barrier rails during soccer matches	Crowd	1100	Sustained	Non-fatal
			2200	Few seconds	Non-fatal
Home Office (1973)	Two cases of traumatic asphyxia	Unknown	6228	15 seconds	Fatal
			1334	4-6 minutes	Fatal
	Recommended tolerance value for safety plus comfort	Unknown	890	Unknown	Non-fatal
	Recommended tolerance value for safety only	Unknown	1335	Unknown	Non-fatal
Fruin (1993)	Estimate of chest loading in fatalities from Ibrox Park soccer stadium incident from body pile height	Crowd	1900	Unknown	Fatal
	Estimate of chest loading in fatalities from Ibrox Park soccer stadium incident from damaged crush barriers	Crowd	2200	Unknown	Unknown
Hopkins *et al.* (1993)	Distributed loads measured by instrumented crush barriers at New Year's Eve celebrations	Crowd	1000	Peak	Non-fatal
			500	30 seconds	Non-fatal
			300	40 minutes	Non-fatal
	Distributed loads measured by instrumented crush barriers at New Year's Eve celebrations	Crowd	2100	Peak	Non-fatal
			900	30 seconds	Non-fatal
			750	10 minutes	Non-fatal
Coutie *et al.* (1993)	Distributed loads measured by instrumented barrier rails during soccer matches	Crowd	900	Peak	Non-fatal
Smith *et al.* (1995)	Loads tolerated against a 1.07 m high steel tube (60 mm diameter) with passive resistance	Adult male volunteers	382	30 seconds	Non-fatal
	Loads tolerated against a 1.07 m high steel tube (110 mm diameter) with passive resistance	Adult male volunteers	444	30 seconds	Non-fatal
	Loads tolerated against a 1.07 m high flat plate (150 mm wide) with passive resistance	Adult male volunteers	474	30 seconds	Non-fatal
McKenzie (2005)	Loads placed on prisoners chests during "peine forte et dure [hard and forceful punishment]"	Male prisoners	1557	30 minutes	Non-fatal
			1779	Few seconds	Non-fatal
			1779	Unknown	Fatal
			1112	7 minutes	Non-fatal
			1677	63 minutes	Non-fatal

1.7 SURVIVAL SPACE

A survival space approach was considered for inclusion in the crashworthiness assessment. Sample operator anthropometric dimensions are presented in Table 5-9.

Table 5-9: Summary of ISO 3411:2007 Earth-moving machinery – physical dimensions of operators and minimum operator space envelope.[1]

Description	Percentile	Dimension (mm)
Seated height	95th	976 + 50* ≈1030
Shoulder (bi-deltoid) width	95th	514
Seated shoulder height	95th	651
Seat Index Point height	95th	97
Chest depth	95th	280
Head length	95th	210
Head breadth	95th	163
Abdominal depth	95th	300

*50 mm for helmet.

If the objective is to prevent entrapment or pinning of the operator, then a volume defined by the operator's seated height and the maximum trunk width or depth, would define the space required to guard the operator (head and trunk) if (hypothetically) they were to retain a seated posture; i.e. 1030 x 514 x 514 (mm). Considering soft-tissue deformation and shoulder girdle movement, the volume could be reduced to 1030 x 500 x 500 (mm). Guarding this volume would maximise within constraints the likelihood of the operator being entrapped by the quad bike. Without a crush protection device or Rollover Occupant Protection System (ROPCS) structure, all quad bikes would fail this requirement. Quad bike operators tend also to be ejected (to varying degrees) and not in an upright seated posture when the quad bike interacts with them.

In the worst case, the operator would be lying parallel to the long axis of the vehicle and would require the length of the trunk and head to be protected. If, hypothetically, the operator remained seated on the Quad bike in an inverted posture, the volume required to fulfil both requirements is 1030 x 1030 x 500 (mm).

[1] ISO 3411 (2007) – Earth-moving machinery – physical dimensions of operators and minimum operator space envelope, International Organisation for Standardisation, Geneva

There is a great deal of variation in the possible postures of the operator and position relative to the quad bike. In the Australian cases reviewed in depth, there were some cases in which the operator remained in the quad bike's seat, albeit in an inverted position. The majority of fatally injured operators were not in a seated posture or position when found. The operator may fall into a tuck position in an inverted position and require less space. With regards to survival space another scenario is that of the operator trapped in a seated position in an inverted position with the quad bike on top. In this situation the operator may be in a flexed posture with his or her trunk folded onto the thighs. With regard to the necessary survival height, dimensions from appendix A have been used. The large operator chest depth is 280 mm (dimension 2D) and thigh clearance is 170 mm (dimension 3F). The total height of the trunk folded onto the thighs is 450 mm for the large (95th %ile) operator. In order to provide additional tolerance and consistency with chest width, 500 mm has been applied as the survival space height. At a minimum the surface area of the chest and abdomen for the 95th percentile male should be protected by a survival space. Using the seat index point height (approximately hip height) and the seated shoulder height, a length requirement is 554 mm. The shoulder width requirement is 500 mm. Therefore, the minimum surface area is 554 mm by 500 mm.

Based on the physical dimensions of the 95th percentile male operator, we propose that a minimum survival space height under the quad bike of 500 mm is required. It is proposed that the proportion of the area greater than the 554 mm by 500 mm contiguous area be measured. For the sake of simplicity this could be rounded down to a survival space of 500 mm x 500 mm x 500 mm. This can be measured under the quad bike in a one-quarter roll resting position and up to two two-quarter roll resting positions for which there is vertical clearance of 500 mm is measured. A scoring system in which full score is provided for areas with a clearance of 500 mm or 1030 mm could be developed. In the latter, the full score would be provided to represent a scenario in which the operator remained in a seated posture. Further consideration could be given for the surfacer area to be greater than the head and trunk combined. At present it is presumed that the majority of quad bikes would receive low or zero scores for survival space. A quad bike might hypothetically provide a single survival space of dimensions 500 mm x 500 mm x 500 mm (height) and could be given a baseline one star. As contiguous volumes greater than 500 mm x 500 mm x 500 mm are observed, the rating increases. The maximum area could be a proportion of an averaged quad bike in plan view.

Measurement of Injury Potential in Quad Bike Crash Tests

Three methods for assessing quad bike operator injury risk are proposed:

1. Measurement of dynamic loads:
    a. Peak impact force on an instrumented surface of appropriate compliance (stiffness) will provide a rating of head and chest injury potential without using an ATD in a laboratory based rollover test. A 3.5 kN criterion would be applied or a suitable discrete rating scale developed. Head acceleration and/or impact force, chest deformation and viscous criterion on an ATD may not be able to measure the impact with the quad bike in a laboratory based rollover test. The quad bike could be dropped or rolled directly onto the ATD's thorax. In this case, the ATD may be damaged in the first test due to the mass of the quad bike. It is unlikely that head acceleration will be a meaningful criterion in this situation because the force applied by the quad bike will be opposed by a ground reaction force.
    b. ATDs used to measure standard parameters in any other test configurations, such as full scale dynamic crash tests or sled tests of ROPS systems.
2. Measurement of static loads. The static loads under the quad bike will provide a measure of the potential in a laboratory based rollover test for:
    a. An assessment of the likelihood of asphyxia due to prolonged compressive loading on the rider (500 N maximum measured for ten minutes).
    b. A rider to extract himself (typically male) from under the quad bike through an assessment of physical strength capacity. The force required to move the quad bike could be measured and compared to standard human strength data.
3. Measurement of survival space. The surface area under the quad bike in a quarter roll and fully inverted position could be measured that has a height (survival space) greater than the minimum requirement (500 mm x 500 mm x 500 mm). This could be measured in a laboratory based rollover test or in a static test against a ground plane.

Test Configurations

There are four potential crashworthiness test configurations in addition to other industry standards for assessing vehicle structures such as ROPS:

1. A dynamic rollover test using a complete quad bike or side-by-side with an ATD. The specific speeds of the quad bike and roll have not been determined. A crash involving forward pitch and roll may be representative of a limited number of real world crashes. Measurements on an ATD may not measure injury related data if the quad bike and ATD do not interact during the crash or if the quad bike loads the ATD in a manner for which the ATD is not sensitive. It should be noted that the ATD separating and falling from the vehicle could measure injury related data, i.e. head or neck ‘diving type’ impact injuries.
2. A low speed lateral and rearward (or forward) roll event from the tilt table onto an instrumented floor. The quad bike is tipped until it rolls. The vehicle rolls onto a floor instrumented with force transducers and covered with an appropriate compliant surface material (to be determined). An alternative is to control the roll so that specified parts of the vehicle interact with an ATD placed on the ground. The ATD could be position on a force platform so that the total impact force is measured in addition to internal ATD measured data. The latter would be challenging.
3. Static tests of survival space and static force. Each quad bike is raised on a hoist and turned over. The quad bike is placed in at least three positions, a quarter roll, and fully inverted in two balanced positions. The static force at the contact points is measured and the height under the vehicle is measured. A 500 mm x 500 mm x 500 mm cube could be constructed of lightweight materials to assess whether there is any usable survival space. An alternative is to place a timber plane over the quad bike in an upright position, apply a set load, and measure the volume between the plane and quad bike.
4. Sled tests of a side-by-side vehicle (SSV) focussing on ROPS restraint systems, occupant containment and vehicle and/or ROPS impact hazards. In these tests the vehicle with the ROPS system is attached to an impact sled, e.g. the Crashlab’s rebound sled. Frontal and lateral impact tests are performed at a set change in velocity and acceleration. ATDs are seated and restrained by the ROPS/vehicle restraint system. The containment of the ATD, e.g. whether the restraints restrict the ATD’s movement to within the ROPS structure, is measured. Impact loading is measured, e.g. head impacts against the ROPS structure or console, using the ATD’s standard parameters. These tests are controlled reproducible laboratory tests. The inclusion of a quasi-static

inversion test could be considered, or at least correlation of ATD movement in an inversion test with ATD movement in the side impact test.

In terms of damage, the static tests will not damage the vehicle and further tests can be undertaken after these tests. It is possible that two rollover tests could be conducted at low speed and at the end of each test the survival space could be measured as per point 3. A dynamic rollover test would be a single test and the vehicle could not be used again. If such tests are considered they need to be the final test of each quad bike.

Operator Safety Rating System Overview

The following is an overview of the proposed operator safety rating system for discussion and consideration. It provides a rating program for all Quad bikes and Side by Side Vehicles.

Zero stars: No survival space, high impact forces in rollover tests, high static load and difficult to displace vehicle manually. Score based on an initial static measurement of survival space and decision regarding laboratory rollover tests based on available survival space and vehicle mass.

One star: A defined survival space, reduced impact forces in rollover tests compared to zero star, static load that can be tolerated for longer period and ability of specified proportion of population to displace vehicle manually. Score based on measurement of survival space and dynamic impact forces (no ATD)

Two stars: More improvement in measures of survival space, impact forces, static load and manual displacement of vehicle. This might represent the limit for quad bikes in their current form. A quad bike with some form of 'crush or operator protection device (CPD/OPD)' might achieve a two star rating.

Three stars: For vehicles with a ROPS meeting an agreed standard (which assesses strength) plus three point seat belts and a suitable internal survival space may be awarded three stars through inspection and static measurements. This would most likely apply to a side-by-side vehicles with ROPS system.

Four stars: A three star vehicle could be submitted for rating to four or five stars. Additional star rating would be achieved through a specified performance with respect to ATD parameters and ATD containment in frontal and side sled tests.

Five stars: The five star vehicle offers superior performance in sled tests with respect to four stars and might include an inversion test.

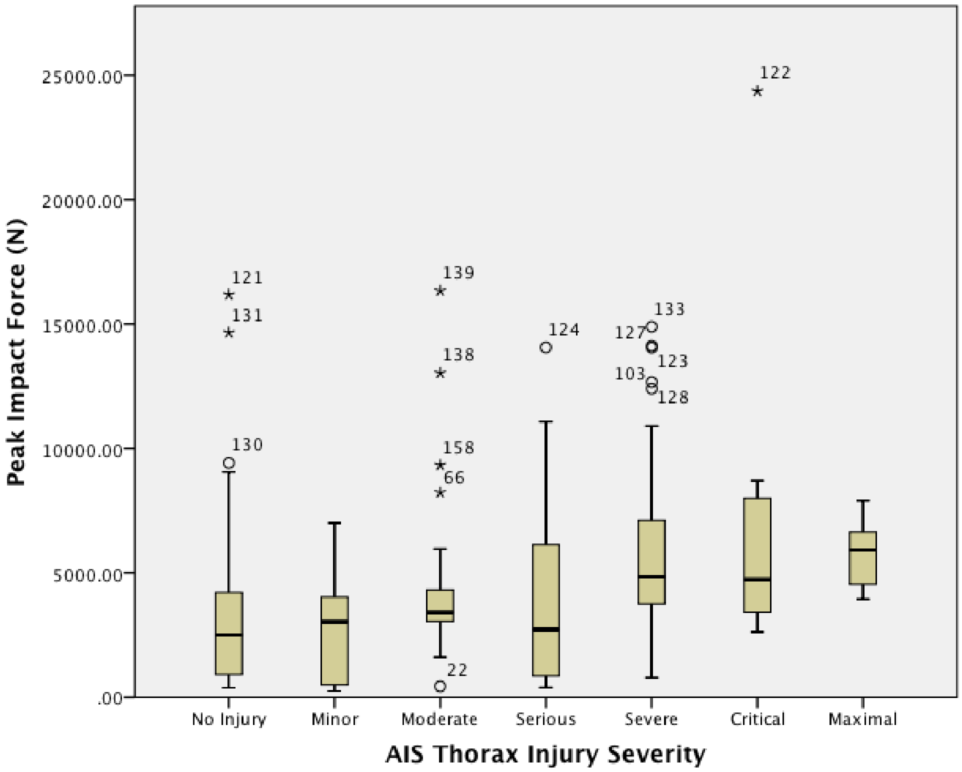
These would be performance tests (except three stars) and the manufacturers would need to resolve restraint geometry issues, padding and strength to score well. One challenge, but common to any test regime, is that there might be an aftermarket ROPS or operator protection device (OPD) for different vehicles. The rating program might also encourage better integrated design of ROPS by vehicle manufacturers.

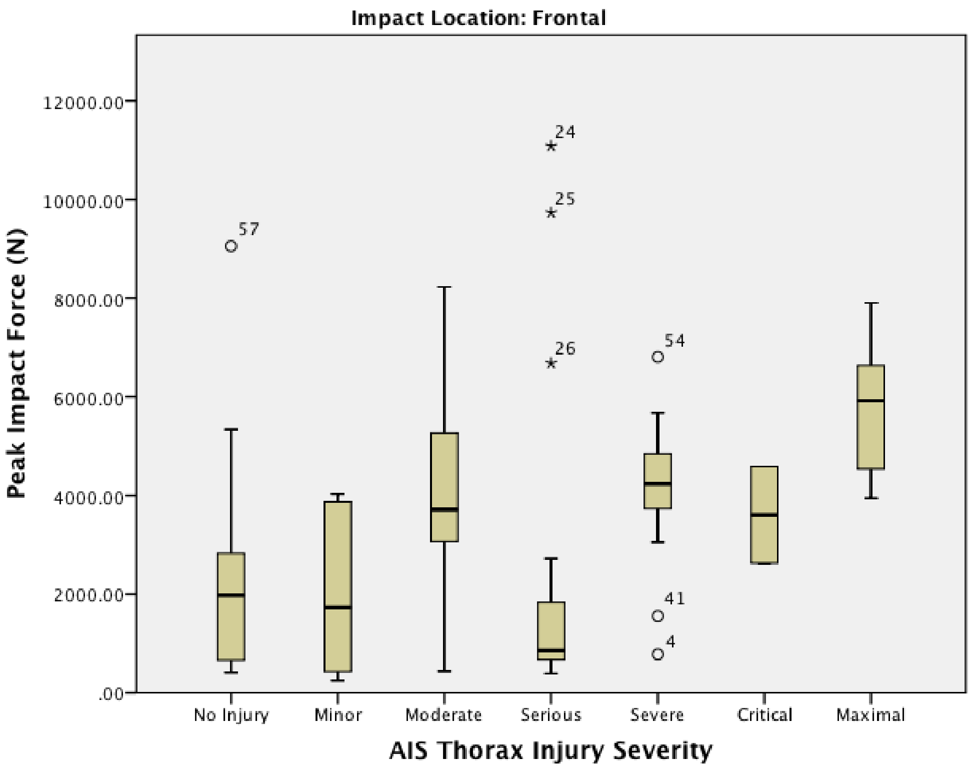
References

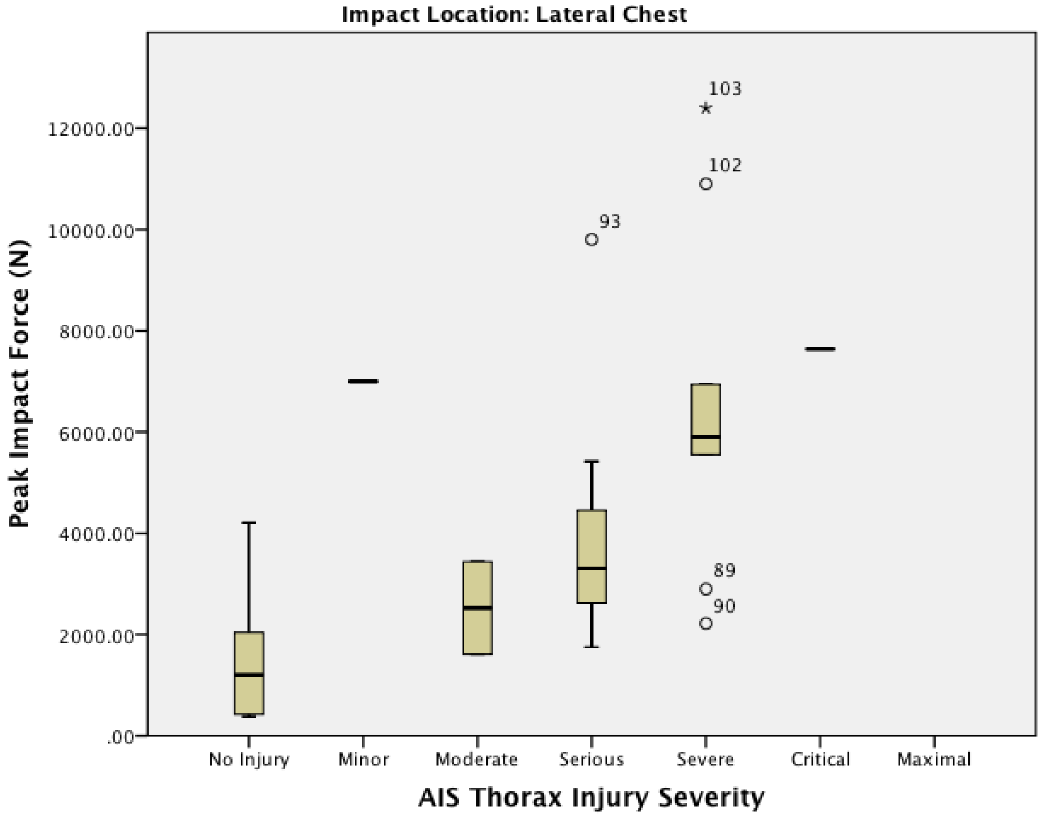
1. d'Angers C-PO. Relation médicale des événements survenus au Champs-de-Mars le 14 Juin, 1837. Ann d'Hyg 1837;18:485-89.
2. Bierman HR, Wilder RM, Jnr, Hellems HK. The Physiological Effect of Compressive Forces on the Torso. Bethesda, MD, USA: Naval Medical Research Institute, 1946:973-90.
3. Evans EJ, Hayden F. Tests on Live Subjects to Determine the Tolerable Forces That May Be Exerted By Crowd Control Crush Barriers: Department of Biomechanics, University of Surrey, 1971.
4. Bingham Blades & Partners. Measurements of Crowd Pressures Generated at Everton Football Club Ground, 1971.
5. Bingham Blades & Partners. Measurements of Crowd Pressures Generated at Liverpool Football Club Ground, 1972.
6. Home Office. Guide to Safety at Sports Grounds. 1st ed. Norwich, England: Her Majesty's Stationery Office, 1973, 1986, 1990, 1997, 2008.
7. The Safety of Sports Grounds Act 1975.
8. Home Office. Crush Barrier Strengths and Spacings. Home Office Note. London, England, 1973.
9. Fruin JJ. The Causes and Prevention of Crowd Disasters. In: Smith RA, Dickie JF, editors. Engineering for Crowd Safety. Amsterdam, The Netherlands: Elsevier Science Publishers, 1993:99-108.
10. Hopkins IHG, Poutney SJ, Sheppard MA. Crowd Pressure Monitoring. In: Smith RA, Dickie JF, editors. Engineering for Crowd Safety. Amsterdam, The Netherlands: Elsevier Science Publishers, 1993:389-98.
11. Coutie MG, Snelson RJ. Measurement of Loadings on Crush Barriers During Football Matches. In: Smith RA, Dickie JF, editors. Engineering for Crowd Safety. Amsterdam, The Netherlands: Elsevier Science Publishers, 1993:409-19.
12. Smith RA, Lim LB. Experiments to Investigate the Level of 'Comfortable' Loads for People Against Crush Barriers. Safety Science 1995;18(4):329-35.
13. Bendjellal F, Walfisch G, Steyer C, Ventre P, Foret-Bruno J. The Programmed Restraint System - A Lesson from Accidentology. 41st Stapp Car Crash Conference: SAE, 1997:249-64.
14. Foret-Bruno J, Trosseille X, Le Coz J, Bendjellal F, Steyer C, Phalempin T, et al. Thoracic Injury Risk in Frontal Car Crashes with Occupant Restrained with Belt Load Limiter. 42nd Stapp Car Crash Conference: SAE, 1998:331-52.
15. McKenzie A. "This Death Some Strong and Stout Hearted Man Doth Choose": The Practice of Peine Forte et Dure in Seventeenth- and Eighteenth-Century England. Law and History Review 2005;23(2):279-314.

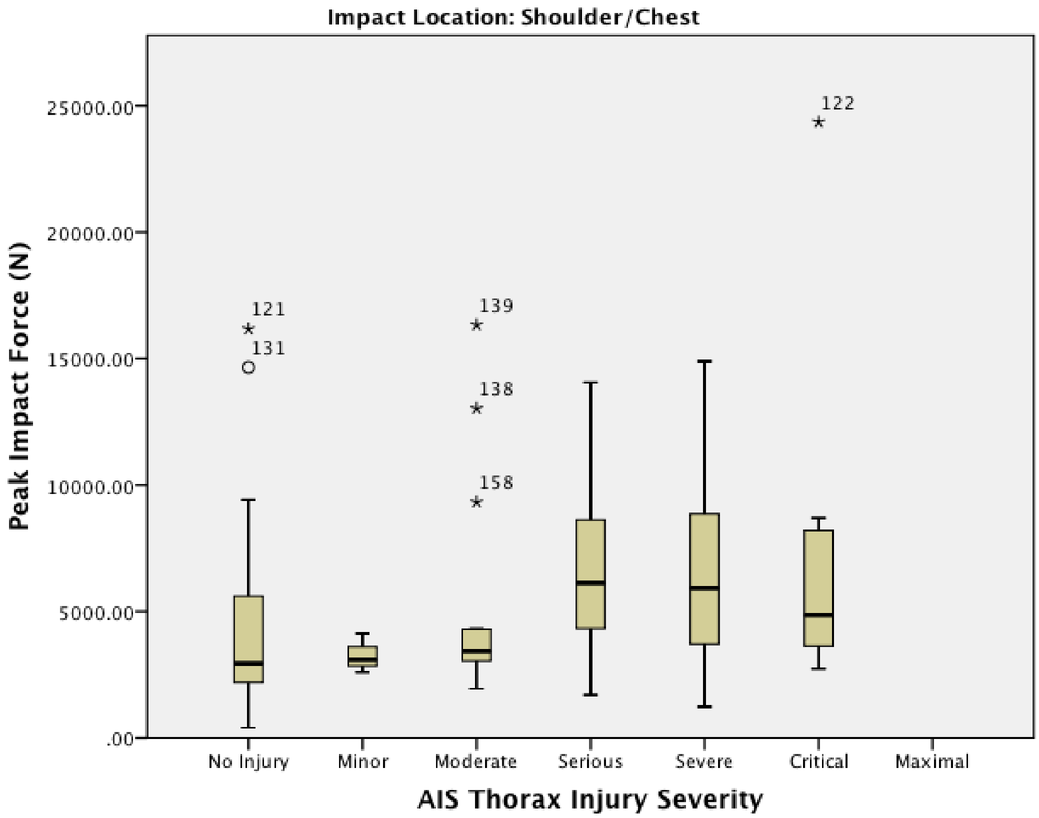
Appendix A: Chest force versus injury severity

Numbers in graphs represent case numbers in the dataset.






Impact Location: Lateral Chest
Peak Impact Force (N)
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
.00
103
102
93
89
90
No Injury
Minor
Moderate
Serious
Severe
Critical
Maximal
AIS Thorax Injury Severity


Impact Location: Shoulder/Chest
Peak Impact Force (N)
25000.00
20000.00
15000.00
10000.00
5000.00
.00
122
121
131
139
138
158
No Injury
Minor
Moderate
Serious
Severe
Critical
Maximal
AIS Thorax Injury Severity