A descriptive review of quad-related deaths in Australia (2011-20)

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Abstract

Objective: To assess Australian quad-related deaths during the 2011–20 period in relation to introduction of the Consumer Goods (Quad Bikes) Safety Standard 2019.

Methods: All Australian quad-related deaths retrieved through the National Coronial Information System.

Results: There were 155 cases, with 116 occurring on a farm and 39 in a non-farm context. Deaths were evenly split between work (52%) and non-work activities, however, 66% of all farm incidents involved work. Rollovers were responsible for 59% of cases and occurred largely on farms (86%), whilst working (69%). Head injury (32%) and asphyxiation (29%) were primary causes of death. Helmet use was low (<5%) in the head injury cases, with 80% of the asphyxiation cases incurring no life-threatening injury other than being entrapped by the quad.

Conclusion: Quad-related deaths are prevalent, with minimal variation in the pattern of incidents from previous Australian studies. Rollover incidents continue to be a major problem especially in a farm context.

Implications for public health: In tandem with existing efforts to enhance behavioural compliance (e.g. helmet use, no child access) and retrofitting Operator Protector Devices, these data support the introduction of the new Standard addressing vehicle stability and fitting Operator Protector Devices to limit potential for asphyxiation.

Key words: quad, ATV, all-terrain vehicle, four-wheel motorcycles, farm

Internationally, there is a growing body of evidence relating to deaths and serious injury associated with the use of quads.[1-3] In Australia and New Zealand, these vehicles are widely used within the agriculture sector and for recreational purposes. Quads are four-wheeled vehicles (sometimes colloquially referred to as quad bikes or ATVs - All Terrain Vehicles), with a straddle seat and handlebars.

As early as the 1980s, significant safety concerns for all-terrain vehicles (inclusive of three and four wheeled vehicles), were raised by the United States Consumer Product Safety Commission (CPSC).[4] Most recently, the CPSC identified that there were between 500-600 deaths annually on quads in the 2015–17 period, with more than 100,000 Emergency Department presentations each year.[3] Furthermore, the CPSC has maintained an ongoing register of deaths since 1982, which contains over 17,000 fatal cases, with over 20% being children.[3,5]

Unlike the US context, the predominate pattern of quad use in Australia (and New Zealand), is agricultural work. Safety concerns were first highlighted in the early 2000s when a study of trends in farm deaths illustrated that while deaths from tractor rollovers had decreased by 74% between 1982–84 and 2001–04, quad-related incidents had increased nearly 13-fold.[1] Since this study there have been several reports which all identified a significant fatality burden (especially in relation to agricultural work).[6-10]

Previous Australian data indicated a statistical difference in the nature of work and non-work fatalities, with work incidents significantly more likely to involve rollovers and asphyxiation/crush injuries. In contrast, non-work cases were more likely to involve non-rollover incidents and head injuries.[7,11] This variation in the pattern and nature of injury, has major implications for work health and safety endeavours, with one coroner labelling quads as "prone to rollover".[12]

As a result of the ongoing trauma related to quads on farms, work health and safety authorities from each of the Australian states and territories, in conjunction with New Zealand, undertook a major review under the auspices of the Heads of Workplace Health Authorities (HWSA). The development group included representatives from the work health and safety authorities, farming groups, Federal Chamber of Automotive Industries (FCAI), representing manufacturers and other interested parties. The basis of the strategy was to examine options based on the Hierarchy of Effectiveness of Controls, as per the national legislation.[13] In summary, this would commence with options to examine elimination (which is not practical given quads are necessary in some situations e.g. flood mustering), substitution (switching to safer alternative vehicles e.g. Side By Side Vehicles), engineering controls (e.g. fitting Operator Protection Devices), administrative controls (e.g. rider training) and personal protective equipment (e.g. helmets). After 18 months of investigation and discussion, the group released an Industry strategy in 2011.[14] However, the FCAI walked out of the

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final meeting and would not endorse the document as it noted "The retrospective fitting of devices designed to reduce the risk to riders from entrapment beneath an overturned vehicle will be supported (but not required) by WHS regulators".[14] These devices are now commonly termed, Operator Protection Devices (OPDs).

Subsequently, a major study (the quad bike performance project), was commissioned through the University of NSW. Given the propensity for rollover of these vehicles (especially in a work context), the aim was to identify the engineering and design features required for improved vehicle stability and rollover crashworthiness, including OPDs.[15] A reference group was formed inclusive of interested stakeholders e.g. FCAI, farming groups, vehicle crash experts etc. Again however, the FCAI representative withdrew from the proceedings, with issues regarding stability testing and the effectiveness of OPDs being at the forefront of their decision.

Building on this history, in 2017 the Australian Competition and Consumer Commission (ACCC), which has a specific product safety mandate, instigated a program to investigate whether a safety standard for all new quads entering Australia (noting no quads are manufactured in Australia), was required to reduce the risk of injury from their use. This systematic consultation process resulted in the publication of a final recommendation to the relevant Commonwealth Minister[16] and the proclamation of the Consumer Goods (Quad Bikes) Safety Standard 2019 (the Standard).[17] The Standard is being introduced in two stages, with the first stage (required by October 2020) including: (a) meeting existing European or USA Standards; (b) having a spark arrestor fitted; (c) having additional safety information on the risk of rollovers affixed to the quad bike and in the owners' manuals; and, (d) being tested for lateral static stability and displaying the angle at which the quad tips on to two wheels on a hang tag at the point of sale. The second stage requirements due to take effect by October 2021, include: (a) meeting a defined lateral roll stability limit (must not tip on to two wheels on a slope less than 28.81 degrees); (b) front and rear longitudinal pitch stability (must not tip on to two wheels on a slope less than 38.65 degrees); and, (c) fitting of an OPD or having one integrated into the quads design. Yet again the manufacturers and their representative agency the FCAI have objected to this Standard.[18]

In the safety realm, the hierarchy of risk controls forms the basis of effectively addressing potential hazards and is enshrined in the Australian Work Health and Safety Regulations (2011).[19] Although there are a range of available preventive approaches to reduce the injury burden associated with quads, engineering controls (which design out or limit the impacts of the hazard), are more effective than administrative approaches such as rider training and personal protection measures (e.g. helmets). Ideally, elements from all levels of the hierarchy of risk controls should be used in tandem, to achieve the best possible outcomes. However, until the specification of the Standard, there has been no progress on addressing the key concerns of stability (i.e. to reduce the propensity for rollover) and operator protection (i.e. minimising harms in the event of a rollover).

This descriptive study builds on a previous paper that assessed quad-related fatalities within Australia over the 2001–10 period.[7] It seeks to outline the nature and scope of fatal quad incidents both in a farm and non-farm setting, from a work and non-work perspective, plus in relation to rollover and non-rollover incidents for the 2011-20 period. Additionally, the study will assess these data in relation to the introduction of the Consumer Goods (Quad Bikes) Safety Standard 2019.[17]

Table 1: Number of quad related deaths by state, year and incident location (n=155).

Location	2010-15	2016-20	Total	%
New South Wales	25	15	40	26
Northern Territory/ South Australia	*	5	9	6
Queensland	28	19	47	31
Tasmania	9	5	14	9
Victoria	22	10	32	21
Western Australia	8	5	13	8
Total	96	59	155	
Farm	72	44	116	75
Non-farm	24	15	39	25

Notes:

**Denotes case numbers < 5*

NT and SA amalgamated due to small numbers

Method

A register of quad deaths is based on information sourced from the National Coronial Information System (NCIS). The NCIS is an internet-based data storage and retrieval system for Australian and New Zealand coronial cases. It contains information about all deaths reported to an Australian coroner since July 2000 (January 2001 for Queensland) and to a New Zealand coroner from 1 July 2007.[20] New cases are added to the register by alerts via a media monitors program, plus coded and key word database searches periodically undertaken using terms including but not limited to: 'quad bike', 'all-terrain', 'ATV', 'four wheel & bike' and '4 wheel & bike'. Data can include police, toxicology, autopsy and Coroners' findings reports for each case that has been finalised and 'closed' by a coroner. However, even prior to cases being 'closed', information pertaining to intent, location, Cause of Death and work-relatedness are often available. Work-relatedness is determined by the relevant work health authority and is also validated by the research team.

Information accessed in the NCIS reports are coded according to the Quad Related Minimum Dataset, developed to assist researchers to accurately describe the injury event.[21] Incidents that are determined by the Coroner to be the result of natural causes or intentional, are excluded from the data. This tool allows for detailed analysis of each case with consideration of human, mechanical and environmental risk factors that lead to the injury event. Data on location (farm/ non-farm), work-relatedness, location (state), age group (including children <15 years), mechanism, activity being undertaken and primary cause of death were assessed. The amount of detail within the register is limited by the information available on NCIS at the time of data retrieval. With 79% (n=122) of the quad cases formally 'closed' by a coroner at the time of data analyses (February 2021), it is expected that there may be additional cases and detail to add to the register over time.

The NCIS contains the Cause of Death Codes as additional fields provided by the Australia Bureau of Statistics (ABS). The ABS utilises the

International Classification of Diseases and Health Related Problems (Tenth Revision) (ICD-10) as the classification system to code cause of death.[22]

Descriptive data were tabulated in SPSSv26, with chi-square analyses to examine variations in farm/non-farm, rollover/non-rollover and primary cause of death.[23] Ethical approval was obtained from the Justice Human Research Ethics Committee CF/19/27527.

Results

There were 155 fatal incidents involving quads in the study period, representing a mean of approximately 15 cases annually. In total, 122 (79%) of the cases had been formally closed by a coroner. Males were involved in 126 cases (81%), with 29 female cases. Total numbers fluctuated both on an annual basis (range 8-22 cases) and within states. The majority of cases (n=119: 77%), occurred in the states of New South Wales, Queensland or Victoria. Overall, 116 (75%) of the cases occurred on a farm (inclusive of work and non-work incidents), with the balance (n=39), in non-farm locations.

Table 2 provides detail relating to the nature of the crash event, location of injury event and whether the machine was being used for work at the time of death. Overall, 52% (n=68) of incidents where work/non-work status was known, involved work. However, there were 18 on-farm cases and six off-farm where work status is yet to be determined. Of the 98 farm incidents where the activity being undertaken was known, 65 (66%) occurred when the machine was being used for work. In contrast, 9% of deaths were associated with a work activity off-farm.

Analysis of the nature of the crash event highlights the leading mechanisms of injury as: rollover with no load or attachments (n=44), collision with stationary object (n=30) and rollover with spray tank (n=17). Overall, rollovers were the mechanism in 59% (n=91) of all incidents.

Rollovers occurred predominantly on farms (86%), with 46 of the 48 work-related rollover deaths occurring in this context. While the total number of on-farm incidents for both rollovers and non-rollovers exceeded that for non-farm deaths, the non-farm deaths were proportionally more likely to involve non-rollovers (67%) and not be work related (90%). The variation between incident location (farm/non-farm) and type of mechanism (rollovers/non-rollovers), was statistically significant (X^2=11.9, df=2, p=0.01). Presence of a load was also identified as a potential risk factor in rollover deaths, with over one third (34%), involving a load or attachment on the machine such as the carrying of passengers, fitment of a spray tank or unit and the towing of trailers.

For the 65 on-farm cases known to be undertaking work at the time of the incident, a notable portion (32%), involved mustering cattle or sheep (n=21). Other activities of note included weed spraying (17%; n=11) and general transport use (15%; n=10).

Table 3 indicates the peak age group for all deaths is 60–74 years (25%), with those 45–59 years (21%) also prominent. The mean age was 47 years (SD 23.5) and median 52 years. Overall, those over 45 years of age made up 60% of total cases. For rollovers specifically, those over 45 years of age were involved in 67% of all incidents. In contrast, non-rollover deaths were most common in the 15–29 year age group (28%), in both the farm and non-farm setting. Children (<15 years) were also present in the data (13%) and included cases on child sized quads. Differences in the age patterns of farm and non-farm deaths (X^2=13.8, df=5, p=0.01) and for rollovers and non-rollovers (X^2=16.8, df=5, p<0.01), were statistically significant.

Table 4 indicates the primary cause of death in relation to the location and the mechanism of the incident, involving a rollover or non-rollover event (n=155). For all cases, head injury was the primary cause of death associated with the greatest proportion of cases (32%), closely followed by other external causes i.e. asphyxiation (29%). Multiple injuries (18%) and thorax injuries (10%) were also prominent causes of death in relation to both rollover and non-rollover injury events. Of the 47 head injury cases, helmet use (yes/no) was known for 33 incidents, with only one case involving a rider with a helmet at the time of the incident. External causes (asphyxiation) dominated the farm-related cases (38%), while head injuries were more prevalent in the non-farm cases (41%).

Analysis of rollovers and non-rollover events indicates a statistically significant variation in the primary causes of death (X^2=28.9, df=5, p=0.01). Rollover deaths were

Table 2: Mechanism of crash event by location and work-relatedness (n=155).

Mechanism	Farm						Off-Farm						All cases	
	Work	%	Non-work	%	Unknown	Sub-total	Work	%	Non-work	%	Unknown	Sub-total	Total	%
Rollover														
No load or attachment	22	24	12	13	5	39	-	-	5	6		5	44	48
Spray tank	15	16	-	-		15	*	*	*	*		*	17	19
Other load including towed	*	*	*	*	-	*	*	*	*	*		*	5	5
Passenger involvement	*	*	6	7	-	7	-	-	*	*	*	*	9	10
Still enquiring	6	7	*	*	6	14		-	*	*	*	*	16	18
Total	46		21		11	78	*		9		*	13	91	
Non-Rollover														
Collison with other vehicle/ animal/ loss of control	5	8	-	-	-	5	*	*	5	8	*	6	11	17
Collision with stationary object	9	10	9	10	-	18	-	-	11	17	-	12	30	47
Rider or passenger falls off	5	6	*	5	*	9	-	-	*	*		*	11	17
Loading/unloading		-		-	-	-	-	-	*	*		*	*	*
Still enquiring		-		-	6	6	-	-	*	*	*	*	8	13
Total	19		12		7	38	*		21		3	26	64	

Note:
**Denotes <5 cases*

predominantly associated with external causes – asphyxiation (46%), head injury (29%) and multiple injuries (12%). In contrast, the majority of non-rollovers were associated with head injuries (36%), multiple injuries (27%) and thorax injuries (14%). Of the 68 cases that were identified as work-related, 70% (n=48) involved a rollover. Of the 45 cases where the primary cause was identified as asphyxiation, there were 31 incidents for which the autopsy report was available for review. Of these cases, 25 incidents (81%), incurred no life-threatening injury other than being entrapped by the quad.

The involvement of alcohol and/or other drugs (AOD), was assessed through toxicological reports. Where reports were available for review, 15% of work-related (n=8) and 43% (n=22) of non-work incidents reported AOD as present. Further, 17% (n=14) of all farm and 65% (n=17) of non-farm incidents, illustrated that AOD may have been a contributing factor in these cases.

Discussion

This descriptive study builds on the literature that has identified quads as a significant mechanism of injury and indicates little to no change in the prevalence or nature of these fatal incidents. As per the original paper in this series covering the 2001–10 period, these data support variations in the nature of traumatic deaths dependent on the location (farm vs non-farm), purpose of use (work vs non-work) and type of incident (rollover vs non-rollover). In this most recent period, there was an average of 15 cases annually (compared with 13 in 2001–10).

Overall, 75% of incidents occurred on farms (65% in 2001–10), with 51% being work-related (67% in 2001–10) and 59% resulting from rollovers (46% in 2001–10). Deaths in the 60-74 year age group were most prevalent, with those over 45 years accounting for almost 60% (43% in 2001–10) and children under 15 years 13% (20% in 2001–10). For all incidents, head injuries (32%) and asphyxiation (29%) were the primary causes of death.

In the sub-samples of farm and non-farm cases, head injuries (41%), were significantly more common in non-farm incidents and asphyxiation (38%) in farm cases. The potential involvement of AOD as a contributing factor to the incidents was particularly high in the non-farm (68%) and non-work (43%) cases. Similar patterns have also been observed in New Zealand, with incidents occurring on-farm (66%), being work-related (56%), involving a rollover (52%) and cause of death being thorax injuries – inclusive of asphyxiation (53%) and head injury (34%).[1] In summary, these data reinforce the importance of helmet use, ensuring children do not ride or be carried as passengers (including smaller child-sized quads that were present in these data), minimising loads (i.e. spray tanks/towing), appropriate vehicle maintenance and not operating vehicles when under the influence of AOD.[14,24] Furthermore, it highlights the importance of programs that promote the use of safer alternate vehicles such as side-by-side vehicles (which is higher in the hierarchy of controls), along with retrofitting OPDs to the existing fleet of quads.

Some groups also emphasise the role that rider training may play, however, there is a paucity of quality evidence that such training makes a difference to fatality or injury outcomes. This position remains unchanged almost 10 years post the original assessment of the 2001–10 Australian data.[7] Indeed, while assessing motorcycle and not quad training, evidence from a randomised control trial suggested that training increased crash-related risk factors including speeding behaviours,[25] replicating an earlier systematic review of the issue.[26] Notwithstanding the efficacy of rider training, the forementioned approaches are aspects which most working in the sector agree may have some utility. However, each of these approaches are at lower levels of effectiveness within the hierarchy of risk controls and all are behaviourally based, escalating the difficulty in ensuring compliance. This is reflected not only in the ongoing cases in these Australian data, but also internationally where decades of effort have been made to address these issues with little impact.[27]

A significant finding in this study was that for the 31 asphyxiation cases where autopsy data were available (from a total of 45 cases), over 80% (n=25) of the decedents incurred no other life-threatening injury i.e. they would have survived the incident if not for the asphyxiation. Furthermore, if this proportional representation were extended to all 45 cases (which will be subject to further investigation as information becomes available), around 36 of the asphyxiation specific deaths (3–4 per year), would have been likely eliminated. These data corroborate previous Australian data for the period 2000–2012, where approximately 20 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

Table 3: Mechanism of injury event by location and age group (n=155).

Age Group (years)	Farm				Non-farm				Sub-Total				Total	
	Rollover		Non- rollover		Rollover		Non- rollover		Rollover		Non- rollover			
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
0–14	14	18	*	11		-	*	8	14	15	6	9	20	13
15–29	*	5	8	21	*	23	10	39	7	8	18	28	25	16
30–44	<10	10	*	11	-	-	6	23	8	9	10	16	18	12
45–59	16	21	7	18	7	54	*	12	23	25	10	16	33	21
60–74	22	28	10	26	*	23	*	12	25	27	13	20	38	25
75+	14	18	5	13	-	-	*	8	14	15	7	11	21	14
Total	78		38		13		26		91		64		155	

Notes:
All figures rounded and may exceed 100%
**Denotes < 5 cases*

Table 4: Primary cause of death by incident location and mechanism (n=155).

Cause of death	Farm		Non-Farm		Total		Rollover		Non-Rollover		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Head	33	28	16	41	49	32	26	29	23	36	49	32
Neck	5	4	*	*	6	4	*	*	5	8	6	4
Thorax	9	8	6	15	15	10	6	7	9	14	15	10
Unspecified	9	8	*	8	12	8	5	5	7	11	12	8
Multiple	16	14	12	31	28	18	11	12	17	27	28	18
External - asphyxiation	44	38	*	*	45	29	42	46	*	5	45	29
Total	116		39		155		91		64		155	

Notes:
All figures rounded and may exceed 100%
**Denotes < 5 cases*

to cause asphyxia".[6] Importantly, these data do not account for other crush injuries associated with the head and thorax that may also benefit from both enhanced stability and fitting of an OPD.

Exploratory testing on the effectiveness of OPDs as part of a broader work program has recently been completed on behalf of the United States CPSC at what was termed minimal (23km/h sled tests and 32-39km/h J-turn tests) and moderate (30km/h sled tests and 38–42km/h J-turn tests) energy rollovers.[28] Whilst there were limitations to this assessment, including lack of clarity around what were deemed 'significant interactions' with the vehicle, results indicated that fitting OPDs reduced the level of potentially injurious interaction to the pelvis, abdomen, thorax or head (5 out of 18) when compared to a quad without an OPD (11 out of 16). However, there was no difference in the final resting position (on the pelvis, abdomen, thorax or head), between those fitted with an OPD (3 out of 18) and those without (3 out of 16). The industry has seized on this later point, proclaiming this demonstrates the futility of fitting an OPD.[29] However, the operation of quads on Australian and New Zealand farms is generally at low speeds. A number of studies have identified that on average 70–80% of usage is at speeds lower than 30km/hr, with quantitative (not self-report) New Zealand data, indicating an average of just 11.4km/hr and an Australian dairy farm specific study, 8.4km/hr.[10,30-32] Consequently, the minimum energy assessments in this CPSC study (23km/hr and 32–39km/hr) may actually be considerably above general operational speeds in the Australian and New Zealand contexts. Notwithstanding this, the minimum energy assessments are likely to be somewhat more representative of farm related incidents than the moderate energy assessments. Further, the one incident in the minimum energy assessments for OPD fitted quads, was on a vehicle that would not meet the stability requirements for Stage 2 of the new Standard and hence, would be excluded from sale in Australia.[33]

There are variations between the CPSC findings and the real-world data from both Australia and New Zealand,[1,15,34,35] with no fatal cases identified where an OPD fitted quad has been linked to the outcome. Additionally, despite actively searching for injury cases involving OPDs, there is only one case of injury (to the leg) where an OPD fitted quad has been reported to come to rest on an operator.[35] By contrast, as indicated in these data, there are numerous such fatal incidents each year without an OPD and there is a 6.5-fold increase in the odds of serious injury where a quad rolls over the operator.[35] This situation is unlikely to simply be a case of lack of exposure to OPDs, as there is currently estimated to be around 30,000 quads with an OPD across both countries.[36,37] Meanwhile, historical estimates indicate that 20% of quads in New Zealand were fitted with an OPD as far back as 2002.[38]

The attention of the manufacturers has been focused on what they term "known safety practices" (e.g. use of helmets).[39] As outlined previously, these are important issues though they are not satisfactory to address the breadth of the problem and especially the burden imposed by rollovers and subsequent asphyxiation. Safe systems principles upon which the Australian road safety strategy is based,[40,41] expects that people will make mistakes and attempts to lessen these impacts by ensuring vehicle design limits injury (e.g. air bags). As such, the 'elephant in the room' continues to be the design of quads, their stability and propensity for rollovers resulting in asphyxiation and crush related injuries. Without addressing engineering design as part of a suite of approaches, it is impossible to make genuine inroads into these statistics. Abrogating this responsibility will no longer be possible for manufacturers given the new Standard.

The industry has indicated its resistance to the ACCC regulations is based on its own commissioned research, which does not support the ACCC findings.[42] However, among numerous critics of the industry research, an independent review commissioned by the ACCC identified that "… the absence of detailed comparisons between the simulations and incident and field tests meant it … *could not have confidence in the simulation modelling or its output*" (emphasis added).[16] Despite this blunt assessment illustrating the lack of validity of the industry funded research, the FCAI and manufacturers continue to publicly propagate this information. What is also not articulated in these industry proclamations, is the total absence of a fatal incident attributable to the presence of an OPD. Indeed, while the industry has claimed there has been two such incidents, this is erroneous and misleading.[43] Relatedly, a field study to examine the potential injury consequences of having an OPD fitted versus no OPD (i.e. setting out to actively identify cases) has been conducted.[35] One component of this study was a survey of quad users (n=1,546), relatively equally represented from Australia and New Zealand. Additional study components included a fleet managers survey (n=16) also involving Australia and New Zealand, plus a quad tour company. While it was recommended that further monitoring of OPD performance be put in place, the findings identified a small number of cases but no serious injury (chest or head) from an OPD. This was suggestive that the OPDs assessed " … reduce to some extent serious chest injuries in rollovers. However, statistical significance was not able to be obtained because of the small sample size of riders receiving injuries when using these OPDs."[35]

The unwillingness of manufacturers to accept the propensity for quad rollovers and enhance vehicle safety (in essence the fundamental foci of the new Australian Standard), has an extensive history dating back to the mid-1980s in the US. Legal action brought against manufacturers by the US CPSC declaring all-terrain vehicles as an "imminently hazardous product" was voluntarily settled by filing a Consent Decree in 1988.[4] A component of this Decree, was a requirement for pitch (front-to-end) stability, but not for lateral stability (which the manufacturers opposed). While the manufacturers agreed to work towards a lateral stability requirement over the 18 months following signing of the Consent Decree, this never eventuated.[44] The industry subsequently developed the American National Standard for Four Wheel All-Terrain Vehicles with the most recent iteration being the 2017 version, which also does not include any lateral stability requirements.[45] As such, some 33 years post the Consent Decree – no definitive action has been taken by the industry.

Stage 2 requirements of the Standard come into force in October 2021. However, the impasse with the FCAI and manufacturers continues, with several major manufacturers indicating they will withdraw from the market in Australia.[46] This is similar to the position taken by manufacturers in Israel, which has had mandatory requirements in place since the early 1990s and which the industry withheld publicly acknowledging in Australia on multiple occasions including a major coronial inquest,[12] a state parliamentary inquiry,[47] development of the HWSA national quad safety strategy[14] and the UNSW quad

safety research project[15] – all of which to some extent addressed the issue of rollover protection. Similarly, the CPSC although dealing with this issue for a protracted period, were not aware of any documentation indicating that the industry raised or discussed the Israeli ROPS requirements with CPSC staff.[48] More recently, the FCAI has continued this obfuscation with public assertions that there is no regulatory requirement for OPDs in Israel (and that the ACCC Standard is faulty).[49] However, a 2020 paper from the Israel National Center for Trauma and Emergency Medicine Research, indicated that "Israel is currently the only country where such devices are mandatory",[2] with the system requiring all quads to undergo an annual registration check with the Ministry of Transport where an OPD must be fitted.[2]

The major manufacturers and FCAI continue to oppose the final introduction of the Standard, including supporting a retailer/farmer lobby group that is targeting politicians in marginal electorates.[50] However, much of the focus of the industry is likely to be on managing the longer-term consequences of Australia's adoption of this Standard internationally and the legal risks that will arise. The industry is feverishly working to prevent uptake of such a Standard (with an apparent immediate target being New Zealand). Not only has New Zealand been part of the HWSA group for many years, Worksafe NZ already "…strongly recommend you install a CPD to reduce the risk of suffocation and crush injuries"[51] and along with three Australian states (NSW, TAS, VIC), New Zealand has a rebate program in place to assist farmers in retrofitting OPDs.[52]

The industry threat to withdraw from selling their products is a warning shot to other countries not to follow the leads set initially by Israel and now Australia. With the Australian market representing less than 5% of global sales, perhaps the major manufacturers can leave the market without any impost on their financial bottom line. However, it is worth noting that several other competitors to the major manufacturers have been proactive in meeting the requirements and some 10 months prior to the Stage 2 requirements being enacted, have products that meet the new Standard. To further complicate matters and place additional pressure on their own franchisees and farmers that may wish to purchase a quad into the future, some major manufacturers have warned franchisees not to stock these alternate brands.[53] These accusations were reported to the ACCC by the franchisees, leading to the ACCC issuing a warning for restriction of trade to the manufacturers.[54]

A further recent move by insurance underwriters for companies manufacturing quads, will also likely add to the impetus for fitting OPDs internationally. Reports have arisen that Lloyds of London, which is one of the global leaders in insurance underwriting, is requiring one of the companies that is committed to meeting the newly promulgated safety Standard, to ensure all their quads are fitted with an OPD immediately rather than awaiting the introduction of the Standard in October 2021.[55]

The manufacturers' recalcitrance to adopt the Standard, can be compared to big-tobacco's resistance in relation to plain packaging (i.e. to reduce wider international uptake).[56] Given the burden of quad fatalities in the US market continues to be 500-600 per annum, with an additional 100,000+ Emergency Department presentations,[3] the potential for litigious action is significant.[3] It is increasingly evident that the industry position is to stop a precedent from being set that may lead to litigation in the critical North American market.

A strength of this study is that it draws on gold-standard data derived from coronial investigations and captures all quad-related deaths in the period. A limitation is that around 20% of all cases had not been finalised by a coroner at the time of analyses. Consequently, it is expected that there will be further detail to add over time. Notwithstanding this limitation, the missing data are relatively modest and given the high level of concurrence with previous data analyses,[6,7,10] are likely to have negligible impact on the interpretation of the data. Although the NCIS provides robust empirical data, there is also a need for forensic engineering assessments to monitor and evaluate the impacts of the stability and OPD requirements in the new Standard moving forward.

Conclusion

This paper describes quad-related fatalities in Australia inclusive of farm and non-farm settings and in relation to work and non-work activity. The data in this study reinforce the ongoing fatality burden imposed by quads, especially in a farm and work context. Consequently, a broadly based approach addressing both behavioural risk factors and design considerations inclusive of retrofitting the existing fleet of quads with OPDs is essential. The implementation of the Standard to enhance design (stability & operator protection) is supported by these data and will require ongoing monitoring and evaluation.

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References

1. Lilley R, Lower T, Davie G. Towards a harmonised approach to reducing quad-related fatal injuries in Australia and New Zealand: A cross-sectional comparative analysis. *Aust NZJ Public Health*. 2017;41:524-9.
2. Siman-Tov M, Marom-Trabelsi I, Radomislensky I, Bodas M, Peleg K. Injuries among all-terrain vehicle users: A population-based study. *Inj Prev*. 2020;26(6):540-5.
3. Topping J. *2020 Report of Deaths and Injuries Involving Off-Highway Vehicles with More than Two Wheels* [Internet]. Bethesda (MD): United States Consumer Product Safety Commission; 2020 [cited 2021 Jan 21]. Available from: https://www.cpsc.gov/s3fs-public/2020-Report-of-Deathsand-Injuries-Invovling-Off-HighwayVehicles.pdf?czH_I.104OtVwPty_gQLdzWIp1SK5ISn
4. US Consumer Product Safety Commission. *CPSC Approves Consent Decrees for All-Terrain Vehicles* [Internet]. Bethesda (MD): CPSC; 1988 [cited 2021 Jan 21]. Available from: http://www.cpsc.gov/en/Newsroom/News-Releases/1988/CPSC-Approves-Consent-Decrees-for-All-Terrain-Vehicles/
5. Topping J. *2018 Annual Report of ATV-Related Deaths and Injuries* [Internet]. Bethesda (MD): United States Consumer Product Safety Commission; 2020 [cited 2021 Jan 21]. Available from: https://www.cpsc.gov/s3fs-public/2018AnnualReportofATVRelatedDeathsandInjuries.pdf?VGaf1cuZ_D0SGxct2eRpZUwcgME4LKDy
6. Grzebieta R, Rechnitzer G, McIntosh A, Mitchell R, Patton D, Simmons K. *Supplemental Report - Investigation and Analysis of Quad Bike and Side By Side Vehicle (SSV) Fatalities and Injuries* [Internet]. Sydney (AUST): University of New South Wales Transport & Road Safety; 2015 [cited 2021 Feb 1]. Available from: http://www.tars.unsw.edu.au/research/Current/Quad-Bike_Safety/Reports/Supplemental_Report_Exam&Analysis_Fatals&Injuries_Jan-2015.pdf
7. Lower T, Herde E, Fragar L. Quad bike deaths in Australia 2001 to 2010. J. Health Saf Environ. 2012;28:7-24.
8. Lower T, Monaghan N, Rolfe M. Quads, Farmers 50+ Years of Age, and Safety in Australia. Safety. 2016;2:12.
9. McBain-Rigg K, Franklin R, McDonald G, Knight S. Why quad bike safety is a wicked problem: An exploratory study of attitudes, perceptions, and occupational use of quad bikes in northern Queensland, Australia. J Agric Saf Health 2014;20:33-50.

10. Wundersitz L, Doecke S, Raftery S, Harrison J. Quad Bikes in South Australia: An Investigation of their Use, Crash Characteristics and Associated Injury [Internet]. Adelaide (AUST): University of Adelaide Centre for Automotive Safety Research; 2016 [cited 2020 Dec 5]. Available from: https://www.researchgate.net/publication/295856475_Quad_bikes_in_South_Australia_an_investigation_of_their_use_crash_characteristics_and_associated_injury_risks
11. Mcintosh A, Patton D, Rechnitzer G, Grzebieta R. Injury mechanisms in fatal Australian quad bike incidents. Traffic Inj Prev. 2016;17:386-90.
12. Olle J. Investigation into Deaths of Vince Tobin, Joseph Jarvis Shepherd, Jye Kaden Jones, Peter Vaughn Crole, Thomas James Scutchings, John Neville Nash, Patricia Murray Simpson, Elijah Simpson with Inquest. Melbourne (AUST). State Coroner Victoria; 2009.
13. Heads of Workplace Safety Authorities. Quad Bike Industry Solutions Program Trans-Tasman Working Group: Industry Strategy for the Reduction of Fatalities and Serious Incidents Resulting from On-farm Use of Quad Bikes [Internet]. Sydney (AUST): HWSA, 2011 [cited 2021 Jan 21]. Available from: http://www.hwsa.org.au/files/documents/Activities%20-%20Current%20Campaigns/6eec848e-c9d7-41a4-a9d5-fe243eef93f2.pdf
14. Grzebieta R, Rechnitzer G, Simmons K, McIntosh A. *Final Project Summary Report: Quad Bike Performance Project Test Results, Conclusions and Recommendations* [Internet]. Sydney (AUST): University of New South Wales Transport & Road Safety; 2015 [cited 2021 Feb 1]. Available from: http://www.tars.unsw.edu.au/research/Current/Quad-Bike_Safety/Reports/Final_Summary_Report4-QBPP_Test_Results_Concl_Recom_Jan-2015.pdf
15. Australian Competition and Consumer Commission. *Quad Bike Safety - Final Recommendation to the Minister* [Internet]. Canberra (AUST): ACCC, 2019 [cited 2021 Feb 1]. Available from: https://www.productsafety.gov.au/system/files/Quad%20Bike%20Safety%20-%20Final%20recommendation%20with%20addendum.PDF
16. Federal Register of Legislation. *Consumer Goods (Quad Bikes) Safety Standard 2019* [Internet]. Canberra (AUST): Government of Australia; 2019 [cited 2021 Feb 1]. Available from: https://www.legislation.gov.au/Details/F2019L01321
17. Federal Chamber of Automotive Industries. *Misleading CPD Proposals Risk Greater Complacency by ATV Users – Putting More Lives at Risk* [Internet]. Melbourne (AUST): FCAI; 2019 [cited 2021 Mar 5]. Available from: https://www.fcai.com.au/news/index/view/news/568
18. Safe Work Australia. *Work Health and Safety Regulations 2011 (Revised as at January 9 2014)* [Internet]. Canberra (AUST): Government of Australia; 2011 [cited 2021 April 28]. Available from: https://www.safeworkaustralia.gov.au/doc/model-work-health-and-safety-act
19. National Coronial Information System. *NCIS Home Page* [Internet]. Melbourne (AUST): NCIS; 2021 [cited 2021 April 28]. Available from: http://www.ncis.org.au/
20. Herde E, Lower T. *Quad Bike Related Injury Minimum Data Set. Vesion 1.1*. Moree (AUST): AgHealth Australia; 2012.
21. National Centre for Classification in Health. *The International Statistical Classification of Diseases and Related Health Problems, 10th Revision, Australian Modification (ICD-10-AM)* [Internet]. Sydney (AUST): University of Sydney Faculty of Health Sciences NCCH; 2005 [cited 2021 Jan 21]. Available from: http://meteor.aihw.gov.au/content/index.phtml/itemId/270546
22. *SPSS*: Statistic package for Windows. Version 26.0. Armonk (NY): IBM; 2019.
23. Australian Centre for Agricultural Health and Safety. *Safety of Quads and other Small Utility Vehicles on Australian Farms. A Practical Management Guide* [Internet]. Moree (AUST): AgHealth Australia; 2016 [cited 2020 Dec 5]. Available from: https://aghealth.sydney.edu.au/wp-content/uploads/2019/05/Safe_Use_Of_Quads_and_SSU.pdf
24. Ivers R, Sakashitaa C, Senserrickb T, et al. Does an on-road motorcycle coaching program reduce crashes innovice riders? A randomised control trial. *Acc Anal Prev*. 2016;86:40-6.
25. Kardamanidis K, Martiniuk A, Ivers R, Stevenson M, Thistlethwaite K. Motorcycle rider training for the prevention of road traffic crashes. *Cochrane Database Syst Rev* [Internet]. 2010 [cited 2021 May 22] Oct 6;(10):CD005240. Available from: https://www.cochrane.org/CD005240/INJ_motorcycle-rider-training-for-preventing-road-traffic-crashes
26. United States Consumer Product Safety Commission. *ATV Safety Information Center* [Internet]. Bethesda (MD): CPSC; 2020 [cited 2021 May 22]. Available from: https://www.cpsc.gov/Safety-Education/Safety-Education-Centers/ATV-Safety-Information-Center
27. US Consumer Product Safety Commission. *Rollover Tests of ATVs Outfitted with Occupant Protection Devices (OPDs) - Results from Tests on Six 2014-2015 Model Year Vehicles* [Internet]. Bethesda (MD): CPSC; 2020 [cited 2021 May 22]. Available from: https://www.cpsc.gov/s3fs-public/SEA-Report-to-CPSC-ATVs-OPDs-final-redacted_0.pdf?VRu656v4QtP5rKliw0kuSQP_hW49TVDK
28. Kebschull S, Van Auken R. *Review of SEA Reports on ATV Rollover and dynamic Sled Tests* [Internet]. Torrance (CA): Dynamic Research; 2020 [cited 2021 May 22]. Available from: http://www.dri-atv-rops-research.com/download/Review%20of%20SEA%20reports%20on%20ATV%20rollover%20dynamic%20and%20sled%20tests,%20DRI-TM-20-135,%202020-10-26.pdf
29. Lower T, Trotter M. *Adoption of Quad Bike Crush Protection Devices*. Moree (AUST): Australian Centre for Agricultural Health and Safety; 2012.
30. Milosavljevic S, McBride D, Bagheri N, et al. Factors associated with quad bike loss of control events in agriculture. *Int J Ind Ergon*. 2011;41:317-21.
31. Schalk T, Fragar L. *Reducing Injury Associated with Farm Motorcycles on Farms in Australia*. Moree (AUST): Australian Centre for Agricultural Health and Safety; 1999.
32. Australian Competition and Consumer Commission. *US Research Shows Roll Bars Likely to Reduce Injuries and Deaths in Quad Bike Rollovers* [Internet]. Canberra (AUST): ACCC; 2020 [cited 2021 Feb1]. Available from: https://www.accc.gov.au/media-release/us-research-shows-roll-bars-likely-to-reduce-injuries-and-deaths-in-quad-bike-rollovers.
33. Lower T. *Submission to ACCC Review - Quad Bike Safety Issues Paper* [Internet]. Moree (AUST): Australian Centre for Agricultural Health and Safety; 2017 [cited 2021 Jan 21]. Available from: https://consultation.accc.gov.au/product-safety/quad-bike-safety-investigation/consultation/view_respondent?uuId=1013085535
34. Grzebieta R, Boufous S, Simmons K, Hicks D, Williamson A, Rechnitzer G. *Quad Bike and OPD Workplace Safety Survey Report: Results and Conclusions* [Internet]. Sydney (AUST): University of New South Wales Transport & Road Safety; 2017 [cited 2021 Feb 1]. Available from: http://www.quadbike.unsw.edu.au/sites/default/files/uploads/Quad_Workplace_Safety_Survey_Report.pdf
35. Australian Competition and Consumer Commission. Estimates on OPD Numbers in Australia 2021. Unpublished Observations.
36. Worksafe New Zealand. Estimates on OPD Numbers in New Zealand 2021. Unpublished Observations
37. Moore D. *A Systems Analysis of Quadbike Loss of Control Events on New Zealand Farms* [PhD Thesis] [Internet]. Palmerston North (NZ): Massey University; 2007 [cited 2021 Jan 28]. Available from: http://mro.massey.ac.nz/handle/10179/624
38. Federal Chamber of Automotive Industries. *ACCC Quad Bike Safety Issues Paper - FCAI Response to Issues Paper* [Internet]. Melbourne (AUST): FCAI; 2017 [cited 2021 Jan 28]. Available from: https://consultation.accc.gov.au/product-safety/quad-bike-safety-investigation/consultation/view_respondent?uuId=401448798
39. Australian Transport Council. *National Road Safety Strategy 2011-2020* [Internet]. Canberra (AUST): Australian Department of Infrastructure, Transport, Regional Development and Communications; 2011 [cited 2021 March 11]. Available from: https://www.roadsafety.gov.au/nrss
40. Office of Road Safety. *National Road Safety Strategy 2021–30 Consultation Draft (February 2021)* [Internet]. Canberra (AUST): Government of Australia; 2021 [cited 2021 March 11]. Available from: https://www.officeofroadsafety.gov.au/sites/default/files/documents/draft-national-road-safety-strategy.pdf
41. Zellner J, Kebschull S, Van Auken R. *Updated Injury Risk/Benefit Analysis of Quadbar Crush Protection Device (CPD) for All-Terrain Vehicles (ATVs)* [Internet]. Torrance (CA): Dynamic Research; 2016 [cited 2021 Jan 28]. Available from: http://www.dri-atv-rops-research.com/download/Updated%20injury%20risk-benefit%20analysis%20of%20Quadbar%20crush%20protection%20device%20(CPD)%20for%20all-terrain%20vehicles%20(ATVs),%20Zellner,%20et%20al,%203rd%20Rev,%202016-08-08.pdf.
42. Federal Chamber of Automotive Industries. *Response to the ACCC's Final Recommendation to the Minister* [Internet]. Melbourne (AUST): FCAI; 2019 [cited 2021 Jan 28]. Available from: https://consultation.accc.gov.au/product-safety/quad-bike-safety-standard-exposure-draft/results/federalchamberofautomotiveindustriesfcai.pdf
43. US Senate: Committee on Governmental Affairs. Hearing before the Committeee on Governmental Affairs United States Senate: One Hundred First Congress. Regulation of All-Terrain Vehicles. US Government, 1990 [cited 2021 Feb1]. Available from: https://babel.hathitrust.org/cgi/pt?id=pst.000017585064&view=1up&seq=7
44. Speciality Vehicle Institute of America. About the ATV Standard. 2017 [cited 2021 Jan 28]. Available from: https://svia.org/about-the-atv-standard/.
45. Federal Chamber of Automotive Industries. FCAI comments on latest American study results for operator protection devices on ATVs. Melbourne: FCAI, 2020 [cited 2021 Jan 28]. Available from: https://www.fcai.com.au/news/index/view/news/663.
46. Victorian Parliamenary Inquiry - Rural and Regional Services and Development Committee - Inquiry into cause of fatality and injury on Victorian farms. Testimony of Mr D. Baines, executive manager, business operations division, Kawasaki (representing the FCAI). Melbourne: Victorian Government, 2004 [cited 2021 Feb 1]. Available from:https://www.parliament.vic.gov.au/archive/rrc/inquiries/farminjuries/transcripts/D%20Baines%20Kawasaki%2012-07-04.pdf.
47. Personal Communication - United States Consumer Product Safety Commission. Declaration of rollover protection devices in Israel. 2015.
48. Federal Chamber of Automotive Industries. Israel ATV myth busted. Melbourne: FCAI, 2020 [cited 2021 Jan 28]. Available from: https://www.fcai.com.au/news/index/view/news/648
49. Anonymous. Save the Quad Bike. 2020 [cited 2021 Jan 28]. Available from: https://savethequadbike.wordpress.com/
50. Worksafe NZ. Policy clarification - Crush protection devices on quad bikes. Wellington: NZ Government, 2019 [cited 2021 Feb 1]. Available from: https://www.worksafe.govt.nz/laws-and-regulations/operational-policy-framework/operational-policies/policy-clarification-crush-protection-devices-on-quad-bikes/#:~:text=CPDs%20are%20designed%20to%20help,if%20the%20quad%20bike%20rolls.&text=This%20includes%20having%20up%2Dto,and%20always%20wearing%20a%20helmet.
51. Accident Compensation Commission. Cash back offer on quad bike crush protection devices. Wellington: NZ Government2020. https://www.acc.co.nz/for-business/workplace-health-safety/cash-back-offer-on-quad-bike-crush-protection-devices/.
52. Hunt P. Yamaha threatens to cancel ATV franchises if dealers sell CF MOTO quad bikes. Weekly Times, Sept 8 2020.
53. Hunt P. ATV: ACCC warning on threats to dealers. Weekly Times, Sept 23 2020.
54. Hunt P. Lloyd's of London says fit ATV rollbars or lose insurance. Weekly Times, March 32021.
55. Chapman S, Freeman B. Removing the emporer's clothes - Australia and tobacco plain packaging. Sydney University Press, 2014 [cited 2021 Feb1]. Available from: https://ses.library.usyd.edu.au/bitstream/handle/2123/12257/9781743324295_Chapman_RemovingtheEmperorsClothes_FT.pdf;jsessionid=EE20778C0EB5DFBCE09573538135746E?sequence=7
56. Lower T. Quad bikes: Tobacco on four wheels. *Aust N Z J Public Health*. 2013;37:105-07.