Injury mechanisms in fatal Australian quad bike incidents

A.S. McIntosh, D.A. Patton, G. Rechnitzer, and R. Grzebieta

ABSTRACT

Objectives: The ability to determine risk management controls for quad bike use is confounded by limitations in crash and injury information. The aim of this article is to identify the injury mechanisms, crash characteristics, and contributing factors in fatal quad bike incidents in Australia by activity (recreation and work).

Methods: An in-depth case series study was undertaken of 106 Australian quad bike fatalities that had occurred between 2000 and 2013. All case material held by Australian coroners was obtained and reviewed.

Results: One hundred and six cases were categorized as occurring during recreation (53) and work (53). Fifty-two of the work cases occurred during farmwork. The mean age for those killed during a work activity was 56 years compared to 27 years for recreational riders. Two children under 16 years died while performing farmwork and 13 children under 16 years during recreational activities. The analyses show a very clear pattern for farmwork-related deaths: quad bike rolls or pitches over (farmworker, 85%; recreational rider, 55%), the rider becomes pinned under quad bike (farmworker, 68%; recreational rider, 30%), and death by asphyxia (farmworker, 42%; recreational rider, 11%). In contrast, recreational riders suffered complex impact injuries to the head and chest that occurred when the rider was traveling at speed, lost control, was ejected, and collided with an object in the environment and/or interacted with the moving quad bike.

Conclusions: The analyses support the need to improve safe quad bike operation through consideration of the age of the rider, training, helmet use, reducing the propensity of quad bikes to roll, and improving handling so that loss of control events are reduced and to prevent crushing and pinning by the vehicle during and after a rollover crash.

Introduction

The safety of quad bikes riders has become a topic of significant interest internationally because of the associated risks of fatal and serious injuries (Lower et al. 2012; Persson 2013; Topping and Garland 2013; Williams et al. 2014). In the current study, a quad bike is defined as a 4-wheel all-terrain vehicle with low-pressure tires that is straddled by the rider/operator, steered using handlebars, and controlled using a small thumb-operated throttle.

Internationally, there are differences in the populations of at-risk riders based on the activities being performed when crashes occur and the crash environments (Denning et al. 2013; Jennissen et al. 2012; Lower et al. 2012; Persson 2013; Topping et al. 2013; Williams et al. 2014). The activities, in general, are work, on-road transport, and recreation. This article will focus on comparing the characteristics of fatal work- and recreation-related off-road crashes and incidents in Australia. Information pertaining to the on-road crashes arising from this study has been previously reported (Grzebieta et al. 2014).

Although research has identified the causes of death and some contributing factors in fatal quad incidents, there are limitations in these data that confound the development and implementation of safety interventions, including engineering controls (Helmkamp et al. 2008, 2012; Lower et al. 2012; Milosavljevic et al. 2011; Rechnitzer et al. 2013; Smith et al. 2005). Engineering controls might focus on improving quad bike handling, protecting the rider in a rollover via an operator (or crush) protection device (OPD), or encouraging the use of side-by-side vehicles (SSV) that have roll cages and seat belt systems (Rechnitzer et al. 2013).

Research to date has shown that blunt force thoracic and head injuries account for large, but varying, proportions of fatal and nonfatal injuries (Helmkamp et al. 2008; Lord et al. 2010; Lower et al. 2012; Miller et al. 2012; Mitchell et al. 2015). Asphyxia has been identified as another common, albeit less frequent, cause of death, accounting for 7 to 16% of cases (Clapperton et al. 2013; Lord et al. 2010; Lower et al. 2012). Characteristics that contribute to an understanding of injury mechanisms, such as ejection, pinning of the rider, and overall pattern of injury, or that contribute to an understanding of the causation of the crash—for example loss of control and intoxication—have not been clearly reported. Rollover is reported as a common crash characteristic, which has been found to account for between 14 and 78% of fatal and injury cases (Balthrop et al. 2007; Finn and McDonald 2010; Hall et al. 2009; Helmkamp et al. 2011; Krauss et al. 2010; Lord et al. 2010; Thepyasuwan et al. 2009). In New Zealand, Shulruf and Balemi (2010) analyzed 355 cases of...
serious harm and 45 fatal cases that involved quad bikes and found a high risk of fatality associated with quad bike rollover and subsequent pinning of the rider. In general, the main off-road crash types are rollover and hitting a stationary object, with contributing factors being speed, terrain, and loss of control (Balthrop et al. 2007; Concannon et al. 2012; Denning et al. 2013; Finn and MacDonald 2010; Hall et al. 2009; Helmkamp et al. 1999, 2011; Krauss et al. 2010; Lord et al. 2010; Lower et al. 2012; Moroney et al. 2003; O’Connor et al. 2009; Shulruf and Balemi 2010; Smith et al. 2005; Thepyasuwan et al. 2009; Wood et al. 2013).

The aim of this article is to identify the injury mechanisms, crash characteristics, and contributing factors in fatal quad bike incidents in Australia by activity (recreation and work).

Methods

Case selection and collation of incident data

An in-depth case series study was undertaken of all Australian quad bike and SSV fatalities for the period 2000–2013. A subset of the quad bike cases is reported in this article. The in-depth analyses distinguish this study from earlier studies by Lower et al. (2012) of similar cases. Fatal case information was initially accessed through the National Coronial Information System (NCIS; Victorian Department of Justice 2013). The NCIS contains data on deaths reported to Australian coroners from July 2000. Only “closed” cases were considered; that is, cases that have been completed by the coroner. The study was approved by institutional ethics committees. Further details of the ethics approvals, search, and case retrieval processes are provided in Appendix A (see online supplement). An initial review of each case was undertaken and a decision was taken regarding case inclusion in the main analysis. Cases were 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 or SSV. This article reports only on quad bike cases.

In-depth case analysis methods

All cases were reviewed and coded according to defined fields (Table 1); the article reports on a subset of those fields. The severity of the most severe injury for the cranium, cervical spine and cervical spinal cord, thorax, and abdomen was coded according to the Abbreviated Injury Scale (AIS) 2005 (Gennarelli et al. 2005). Field entries were reduced to standard descriptor codes for statistical analyses. Descriptive analyses and calculation of odds ratios (ORs) were undertaken using IBM SPSS Statistics release 21. ORs should be considered with caution because there are no exposure or nonfatal control data.

Results

Case selection

A total of 141 closed fatal cases were identified, of which 106 were included in the quad bike case series analysis: 53 work and 53 recreation by activity. Thirty-five cases were excluded for specific reasons—for example, SSV, public road crashes. All but one

| Table 1. All cases were coded according to the following fields. |
|-----------------|-----------------|-----------------|
| **Topic**       | **Fields**      | **Comments**    |
| Human factors   | Gender, age, stature and body mass, recreation or work, specific activity at time of incident, industry (work-related), helmet, toxicology | Stature and body mass were not always measured or reported. Age groups were based on Australian Bureau of Statistics (2014) definitions |
| Temporal        | Month, season, day of week, time of incident, time of death, interval between incident and death | Time of day during the week was analyzed according to the method developed by McLean et al. (1980) |
| Vehicle         | Type (quad bike, side-by-side, other), make, model, engine capacity, build year, attachments at time of incident, crush protection device | Make, model and other vehicle details were not always documented in the case files |
| Environment     | Terrain, ground cover, slope, collision partner | Photographs of the environment were considered |
| Crash Injury    | Cause of death (region, nature and main mechanism), pinning of rider, injuries by body region and anatomical part, Maximum AIS coding of cranium, cervical spine, thorax and abdomen, asphyxia, mechanisms of main injuries, free text | AIS 2005 used for coding MAIS (Gennarelli and Wodzin 2005) |

work case were in the agriculture sector (farming). Farm-related incidents occurred on farms during farming work; for example, mustering, spraying, transport, and maintenance.

Human factors

Ninety-two (86.8%) of the cases were male. The median age for those killed during a work activity was 59 years compared to 24 years for recreational riders. Two children under 16 years died while performing farmwork (3.8%), compared to 13 children under 16 years who died during recreational activities (24.5%). In the work setting, 81.1% of those killed were older than 45 years, whereas 84.9% of the cases in the recreational setting were less than 45 years. Additional demographic details are presented in Tables A1 to A4 (see online supplement).

A helmet was worn in 22 cases. In 4 of these 22 cases, the helmet was ejected. Only one person involved in a farmwork incident was wearing a helmet. The majority (77.4%) did not wear a helmet.

Forty-two work cases and 26 recreation cases tested negative for alcohol and/or drugs, with 6 unknowns (4 work and 2 recreation). Among the 7 work cases that tested positive for alcohol and/or drugs, in one the blood alcohol concentration was greater than 0.1 g/dl, in 5 cases toxicology detected recreational drugs, and in one case a central nervous system–active clinical mediation was at a toxic level. Twenty-five of the fatal recreational cases tested positive for alcohol and/or drugs. In 13 of the 25 cases, the blood alcohol concentration was greater than 0.1 g/dl. For the 100 cases with known levels of intoxication, workers were 83% less likely to be intoxicated than recreational riders (OR = 0.173,
95% confidence interval [CI], 0.066–0.457; Table A5, see online supplement).

**Vehicle factors**

The largest supplier of vehicles was Yamaha \( n = 35, 32.1\% \), followed by Honda \( n = 24, 22.0\% \) and Suzuki \( n = 14, 12.8\% \). The model year and engine capacity were not known in sufficient cases to report in detail, although the majority of the reported engine capacities were greater than 250 cc. In the 15 children aged up to and including 15 years, the engine capacity was unknown in 4 cases and between 50 and 450 cc for the remaining cases, including 6 between 250 and 450 cc. Among the 7 16- and 17-year-olds, the engine capacity was in the range 200 to 450 cc. Many farmworkers \( (\approx 50 \text{ to } 75\%) \) had one or more attachments on the vehicle. Attachments ranged from a toolbox to a spray tank. In contrast, few recreational riders had an attachment on the vehicle \( (\approx 25 \text{ to } 33\%) \). Recreational riders were more likely to carry a passenger than farmworkers.

**Crash characteristics**

Of the 106 cases, 72.6% occurred on a farm, 9.4% in state forests, and 7.5% on beaches (Table A6, see online supplement). The exact speed or a usable speed estimate was not reported in 81.1% of the cases. The 2 main crash initiators were "loss of control caused by object" \( (18.9\%) \) and "loss of control on slope" \( (17.9\%\); Table A7, see online supplement). The vehicle definitely rolled in 74 of the 106 cases \( (69.8\%) \). Forty five of the work cases \( (84.9\%) \) involved a rollover compared to 29 \( (54.7\%) \) of the recreational cases. For the 106 cases, workers were 4.7 times more likely to be involved in a rollover than recreational riders \( (OR = 4.655, 95\% CI, 1.843–11.755; Table A5) \).

**Cause of death and injury mechanisms**

The head \( (32.1\%) \) and chest \( (36.8\%) \) accounted for the majority of fatal injuries by body region (Table 2). Head injury was the main cause of death for recreational quad bike riders \( (50.9\%) \) compared to chest injury in farmworkers \( (58.5\%) \). The distribution of injuries by body region and severity, including non-fatal injuries, was analyzed (Tables A8 and A9, see online supplement). When head injuries are considered by activity, 11.3% of farmworkers suffered a skull fracture compared to 54.7% of recreational riders, and 20.8% of farmworkers suffered a traumatic brain injury \( (\text{TBI}) \) compared to 69.8% of recreational riders. For the 106 cases, there was an 89.4% reduction in the likelihood of skull fracture and 88.7% reduction in likelihood of brain injury among workers compared to recreational riders (Table A5).

In total, the cause of death in 28 \( (26.4\%) \) cases was asphyxia, including 22 farmworkers and 6 recreational riders (Table 3). For the 106 cases, workers were 5.6 times more likely than recreational riders to be asphyxiated \( (OR = 5.559, 95\% CI, 2.024–15.266; Table A5) \). In addition, there were 6 sustained crush–related conditions (three deaths by a combination of asphyxia and drowning and three crush–related deaths related to vascular system obstruction). There was one unknown cause of death that occurred after the person had been pinned under the vehicle. Asphyxia was also coded by the body region most associated with the cause of asphyxia as per the autopsy; for example, if the chest was crushed, chest was the body region partnered with asphyxia. The vast majority of those who died of asphyxia or a similar sustained crush–related condition had no head, cervical spine, or abdominal injury. In 15 of the 26 asphyxia cases \( (58\%) \), a chest injury of AIS severity of at least 3 was also present, which included 1 AIS = 3 severity scores in farmwork cases.

Fifty-two \( (49.1\%) \) of the deceased riders were pinned by the quad bike; that is, the person was restrained and crushed by the vehicle until released by another person. Workers were 4.9 times more likely than recreational riders to be pinned by the quad bike \( (OR = 4.897, 95\% CI, 2.151–11.147; Table A5) \). All 28 cases of asphyxia involved the deceased being pinned by the vehicle. Approximately \( 39\% \) of the farmworkers and \( 63\% \) of recreational riders who were pinned were not asphyxiated.

**Discussion**

An in-depth case series analysis of 106 fatal Australian quad bike cases revealed differences in the incident characteristics and injuries by activity. Although all material was collected, there were still many limitations in terms of the availability of site surveys, witness statements, and documentation of witness marks from the perspective of reconstructing the incidents to estimate speeds and other characteristics.

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. The mean height and body mass for all included cases in the age group 16 to 74 years \( (n = 80) \) were 1.75 m and 81 kg, respectively. This compares to the mean height and body mass for the adult male U.S. population of 1.77 m and 83 kg, respectively (International Organisation for Standardisation 2010).

The analyses show a very clear pattern for farmwork-related deaths: quad bike rolls or pitches over \( (\text{farmworker} = 85\%; \text{recreational rider} = 55\%) \), rider becomes pinned under quad bike \( (\text{farmworker} = 68\%; \text{recreational rider} = 30\%) \), and death by asphyxia \( (\text{farmworker} = 42\%; \text{recreational rider} = 11\%) \). In contrast, recreational riders suffered complex impact–related injuries to the head and chest that occurred when the rider was traveling at speed, lost control, was ejected, or collided with an object in the environment and/or interacted with the moving quad bike. Intoxication in combination with speed and/or fatigue, which are well-understood factors in trauma, were present in the recreational cases but not representative of work cases (Appendix A; Lin and Kraus 2009).

Almost half of the farmwork fatalities \( (n = 26) \) were caused by asphyxia or a similar sustained crush–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. Thoracic injuries—for example, fractured ribs—were classified as none in 12 cases, moderate in 2 cases, serious in 10 cases, and 2 severe or critical. The data suggest strongly that approximately 20 of the farmworkers who died of asphyxia in a sustained crush–related condition would have survived if the vehicle did not pin them with a force sufficient in terms of magnitude and duration to cause asphyxia. In the other fatal farmwork cases,
Table 2. Cause of death (body region) by activity at time of crash.

| Cause of death—body region | Work | | Recreational | | Total |
|----------------------------|------|------|---------------|------|------|
|                            | Number | Percentage | Number | Percentage | Number | Percentage |
| Head                       | 7      | 13.2   | 27      | 50.9   | 34     | 32.1       |
| Neck<sup>a</sup>           | 9      | 17.0   | 4       | 7.5    | 13     | 12.3       |
| Chest                      | 31     | 58.5   | 8       | 15.1   | 39     | 36.8       |
| Abdomen                    | 1      | 1.9    | 2       | 3.8    | 3      | 2.8        |
| Thigh                      | 0      | 0.0    | 1       | 1.9    | 1      | 0.9        |
| Multibody                  | 4      | 7.5    | 10      | 18.9   | 14     | 13.2       |
| Positional asphyxia        | 0      | 0.0    | 1       | 1.9    | 1      | 0.9        |
| Unknown<sup>b</sup>        | 1      | 1.9    | 0       | 0.0    | 1      | 0.9        |
| Total                      | 53     | 100.0  | 53      | 100.0  | 106    | 100.0      |

<sup>a</sup>Neck region includes the cervical spine.

<sup>b</sup>The unknown case was an open finding with regards to cause of death.

A large proportion of those not asphyxiated were injured when the quad bike interacted with the rider during a rollover, causing impact-related injuries.

The data support the need for higher helmet wearing rates for recreational riders but indicate that higher helmet wearing rates may have altered the incidence of fatal farmwork crashes only slightly (Miller et al. 2012). The value of helmets may be greater in preventing nonfatal traumatic brain injuries in the farmwork setting.

The analyses indicate that reducing the propensity for the vehicle to roll, improving handling so that loss of control events are reduced, and managing the interaction between the vehicle and the rider in a rollover to prevent crushing are 3 important areas of crash prevention and crashworthiness with regards to fatal quad bike incidents. Training of quad bike riders and age-based restrictions require consideration; at least half of the children killed were riding adult-sized quad bikes. Older males represented the typical farmwork fatality. The use of quad bikes for prolonged periods of work by older people on farms may be problematic because of the active riding and fine motor control required to operate a quad bike. From a risk management perspective, the analysis indicates that farmers should consider substituting SSVs with a rollover occupant protection system (ROPS) system and seat belts for a quad bike. Where an SSV is not an option, engineering controls, such as an OPD, may be considered for farmwork in particular. An OPD may function to reduce (a) contact or entanglement of the rider with the vehicle; (b) entrapment of the rider between the vehicle and the ground; and (c) forces applied by the quad bike to the rider. Multiple risk controls for recreational quad bike riders are challenging but need to be applied, because of the multifactorial causal factors, including speed, failure to wear a helmet, and, fatigue and/or intoxication (Mangus et al. 2004; Miller et al. 2012). Ongoing in-depth and timely investigation of quad bike and SSV incidents—fatal, injury, and no injury—with exposure measures will assist in understanding risks and developing effective interventions. Research and development of controls is needed with regards to vehicles, focusing on stability, handling, occupant protection in a rollover, rider behaviors, and helmets.

Table 3. Asphyxia/sustained crush–related cause of death by activity and nominated cause of death by body region<sup>a</sup>.

| Cause of death by body region | Recreational | | Work | | All |
|------------------------------|--------------|------|------|------|------|
| Asphyxia/sustained crush     | Asphyxia/sustained crush | Not asphyxiated | Asphyxia/sustained crush | Not asphyxiated | Asphyxia/sustained crush | Not asphyxiated |
| Head                         | 0, 0.0       | 27, 60.0 | 0, 0.0 | 7, 26.9 | 0, 0.0 | 34, 47.9 |
| Neck (including cervical spine) | 0, 0.0       | 4, 8.9  | 3, 11.5 | 6, 23.1 | 3, 8.8  | 10, 14.1 |
| Chest                        | 6, 75.0      | 2, 4.4  | 22, 84.6 | 9, 34.6 | 28, 82.4 | 11, 15.5 |
| Abdomen                      | 0, 0.0       | 2, 4.4  | 0, 0.0  | 1, 3.8  | 0, 0.0  | 3, 4.2   |
| Thigh                        | 0, 0.0       | 1, 2.2  | 0, 0.0  | 0, 0.0  | 0, 0.0  | 1, 1.4   |
| Multibody                    | 1, 12.5      | 9, 20.0 | 1, 3.8  | 3, 15.5 | 2, 5.9  | 12, 16.9 |
| Positional asphyxia          | 1, 12.5      | 0, 0.0  | 0, 0.0  | 0, 0.0  | 1, 2.9  | 0, 0.0   |
| Deceased pinned              | 8, 100.0     | 8, 17.8 | 25, 96.2 | 10, 38.5 | 33, 97.1 | 18, 25.4 |
| Yes                          | 0, 0.0       | 37, 82.2 | 1, 3.8 | 16, 61.5 | 1, 2.9 | 53, 74.6 |
| No                           | 8, 100.0     | 8, 17.8 | 25, 96.2 | 10, 38.5 | 33, 97.1 | 18, 25.4 |
| Mechanism of injury<sup>b</sup> | 6, 75.0      | 2, 4.4  | 24, 92.3 | 9, 34.6 | 30, 88.2 | 11, 15.5 |
| Crush                        | 2, 25.0      | 8, 17.8 | 1, 3.8  | 5, 19.2 | 3, 8.8  | 13, 18.3 |
| Crush-impact loading         | 0, 0.0       | 0, 0.0  | 1, 3.8  | 0, 0.0  | 1, 2.9  | 0, 0.0   |
| Drowning (pinned)            | 0, 0.0       | 0, 0.0  | 1, 3.8  | 0, 0.0  | 1, 2.9  | 0, 0.0   |
| Impact                       | 0, 0.0       | 35, 77.8 | 0, 0.0 | 12, 46.2 | 0, 0.0 | 47, 66.2 |

<sup>a</sup>Single case of “asphyxia unknown” excluded from table. Therefore, total count is 105.

<sup>b</sup>The mechanism of injury was based on a professional judgment using the description of the event and injuries. For example, a person with severe TBI and skull fracture would suffer an impact injury, a person who was asphyxiated with minor other injuries was crushed, and a person with a combination of impact and crushing injuries was “crush-impact loading.”
Acknowledgments

The authors acknowledge and thank the members of the international QBPP Project Reference Group for their valuable input to the project and the Victorian Institute of Forensic Medicine (VIFM) as the source organisation of the National Coroners Information System (NCIS) from which rollover crash data were extracted for the Australian fatal data presented in this article. The authors also thank Joanna Cotsonis for her assistance as the NCIS Access Liaison Officer for the QBPP and all of the state coroners for allowing access to the full brief of evidence for the Australian quad bike fatality cases. The authors also thank the court staff members who were extremely helpful during correspondence and visits: Australian Capital Territory, Michelle Heidtmann and Alison Purvis; Victoria, Lisa Brodie and Angela Belegrinos; Tasmania, Kelly Medhurst and Jenny Scott; South Australia, Michele Bayly-Jones and Delia O’Neill; Western Australia, Kate Ellison, Sue Wilde, Karen Harding, and Amy Heu; Northern Territory, Alana Carter; Queensland, Leanne Field; New South Wales, Ann Lambino; and all of the members of the local courts who assisted in the retrieval and copying of case files.

Funding

The authors gratefully acknowledge the Workcover Authority of NSW for funding the the work presented in this article within the Quad Bike Performance Project (QBPP), in particular, Tony Williams and Diane Vaughan. The Australian Consumer and Competition Commission (ACCC) also contributed funds to the QBPP. In response to the incidence of fatal and serious injury rollovers involving quad bikes in the Australian farming sector, the Australian Heads of Workplace Safety Authorities (HWASA) and the Quad Bike Industry Working Group Strategy (Design) for improving the safety of quad bikes in the farm environment supported the funding of the QBPP at the Transport and Road Safety (TARS) Research unit at the University of NSW. Neither Workcover NSW nor the ACCC had a role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. The opinions expressed in this article are those of the authors.

References

Australian Bureau of Statistics. *Australian Demographic Statistics*. Sydney, NSW, Australia: Author; 2014.

Balthrop PM, Nyland JA, Roberts CS, Wallace J, van Zyl R, Barber G. Orthopedic trauma from recreational all-terrain vehicle use in central Kentucky: a 6-year review. *J Trauma*. 2007;62:1163–1170.

Clapperton AJ, Herde E, Lower T. Quad bike related injury in Victoria, Australia. *Med J Aust*. 2013;199:418–422.

Concannon E, Hogan A, Lowery A, Ryan RS, Khan W, Barry K. Spectrum of all-terrain vehicle injuries in adults: a case series and review of the literature. *Int J Surg Case Rep*. 2012;3(6):222–226.

Denning DA, Harland KK, Ellis DG, Jennissen CA. More fatal all-terrain vehicle crashes occur on the roadway than off: increased risk-taking characterises roadway fatalities. *Inj Prev*. 2013;19(4):250–256.

Finn MA, MacDonald JD. A population-based study of all-terrain vehicle-related head and spinal injuries. *Neurosurgery*. 2010;67:993–997.

Gennarelli T, Wodzin E. *Abbreviated Injury Scale 2005*. Barrington, IL: Association for the Advancement of Automotive Medicine; 2005.

Grzebieta RH, Rechnitzer G, McIntosh AS, Simmons K, Mitchell R, Patton DA. Road related quad bike and side by side vehicle casualties. Paper presented at: Australasian Road Safety Research, Policing & Education Conference; November 12–14, 2014; Melbourne, Australia.

Hall AJ, Bixler D, Helmkamp JC, Kranner JC, Kaplan JA. Fatal all-terrain vehicle crashes: injury types and alcohol use. *Am J Prev Med*. 2009;36:311–316.

Helmkamp JC, Aitken ME, Graham J, Campbell CR. State-specific ATV-related fatality rates: an update in the new millennium. *Public Health Reports*. 2012;127:364–374.

Helmkamp JC, Furbee PM, Coben JH, Tadros A. All-terrain vehicle-related hospitalizations in the United States, 2000–2004. *Am J Prev Med*. 2008;34:39–45.

Helmkamp JC, Marsh SM, Aitken ME. Occupational all-terrain vehicle deaths among workers 18 years and older in the United States, 1992–2007. *J Agric Saf Health*. 2011;17(2):147–155.

Helmkamp JC, O’Hara FJ, David J-A. All-terrain vehicle-related deaths: West Virginia, 1985–1997. *MMWR Morb Mortal Wkly Rep*. 1999;48:1–4.

International Organisation for Standardisation. Part 2: *Statistical Summaries of Body Measurements from Individual ISO Populations*. Geneva, Switzerland: Author; 2010.

Jennissen C, Harland K, Ellis D, Denning G. All-terrain vehicles: deadly on and off the road. *Inj Prev*. 2012;18(Suppl 1):A192–A193.

Krauss EM, Dyer DM, Laupland KB, Buckley R. Ten years of all-terrain vehicle injury, mortality, and healthcare costs. *J Trauma*. 2010;69:1338–1343.

Lin M-R, Kraus JF. A review of risk factors and patterns of motorcycle injuries. *Accid Anal Prev*. 2009;41:710–722.

Lord S, Tator CH, Wells S. Examining Ontario deaths due to all-terrain vehicles, and targets for prevention. *Can J Neurol Sci*. 2010;37:343–349.

Lower T, Herde E, Fragar LJ. Quad bike deaths in Australia 2001 to 2010. *J Health Safety Environ*. 2012;2:87–24.

Mangus RS, Simons CJ, Jacobson LE, Streib EW, Gomez GA. Current helmet and protective equipment usage among previously injured ATV and motorcycle riders. *Inj Prev*. 2004;10:56–58.

McLean AJ, Holubowycz OT, Sadowl BW. Alcohol and Crashes: Identification of Relevant Factors in this Association. *Adelaide, SA, Australia: Road Accident Research Unit, University of Adelaide; 1980.*

Miller M, Davidov D, Tililoton R, Whiteman C, Marshall T, Lander O. Injury prevention and recreational all-terrain vehicle use: the impact of helmet use in West Virginia. *W V Med J*. 2012;108(3):96–101.

Milosavlic S, McBride DI, Bagheri N, et al. Factors associated with quad bike loss of control events in agriculture. *Int J Ind Ergon*. 2011;21:317–321.

Mitchell RJ, Grzebieta RH, Rechnitzer G. Capture and surveillance of quad-bike (ATV)-related injuries in administrative data collections. *Int J Inj Contr Saf Promot*. 2015;7:1–9.

Moroney P, Doyle M, Mealy K. All-terrain vehicles—unstable, unsafe and unregulated: a prospective study of ATV-related trauma in rural Ireland. *Injury*. 2003;34(3):203–205.

O’Connor T, Hanks H, Steinhardt D. All-terrain vehicle crashes and associated injuries in North Queensland: findings from the rural and remote road safety study. *Aust J Rural Health*. 2009;17(5):251–256.

Persson J. *Better Safety on Quad Bikes*. Borås, Sweden: Swedish Transport Administration; 2013.

Rechnitzer G, Grzebieta RH, McIntosh AS, Simmons K. Reducing all-terrain vehicle injuries (ATVs) and deaths—a way ahead. Paper presented at: 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV); May 27–29, 2013; Seoul, South Korea.

Shulruf B, Balemi A. Risk and preventive factors for fatalities in all-terrain vehicle accidents in New Zealand. *Accid Anal Prev*. 2010;42:612–618.

Smith LM, Pittman MA, Marr AB, et al. Unsafe at any age: a retrospective review of all-terrain vehicle injuries in two level I trauma centers from 1995 to 2003. *J Trauma*. 2005;58:783–788.

Thepaysawan N, Wan XT, Davis VJ. All-terrain vehicle injuries at Arrowhead Regional Medical Center (level II): epidemiology, risks, and outcome. *Am Surg*. 2009;75:1004–1008.

Topping J, Garland S. 2012 Annual Report of ATV-Related Deaths and Injuries. Betheseda, MD: Consumer Product Safety Commission; 2013.

Victorian Department of Justice. *National Coronial Information System*. Southbank, VIC, Australia: NCIS; 2013.

Williams AF, Oesch SL, McCarrt AT, Teoh ER, Sims LB. On-road all-terrain vehicle (ATV) fatalities in the United States. *J Safety Res*. 2014;50:117–123.

Wood A, Duijff JW, Christey GR. Quad bike injuries in Waikato, New Zealand: an institutional review from 2007–2011. *ANZ J Surgery*. 2013;83(4):206–210.