

Injuries from All Terrain Vehicles An Opportunity for Injury Prevention

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Abstract- In 2004–2005, legislation restricting all-terrain vehicle (ATV) use by children and an extensive social marketing campaign intended to reduce pediatric ATV-related morbidity. The frequency, nature, and severity of pediatric ATV-associated trauma were compared before and after such interventions. **Methods:** A retrospective cohort study was performed for all pediatric ATV-related injuries that presented to the provincial level 1 pediatric trauma center from 1998 to 2014. National databases were queried for ATV-related injury hospitalizations ($n = 258$), trauma center emergency department visits ($n = 342$), and admissions ($n = 136$) in Nova Scotia from 2002 to 2014. Admissions between 1998 and 2003 ($n = 68$) and 2006–2014 ($n = 60$) were compared using chi square analysis for age and gender distribution, length of stay, critical care admission, helmet use, mechanism, and severity of injury. **Results:** Admissions, trauma center emergency room visits and admissions initially decreased following legislative and social marketing interventions and subsequently gradually increased. Interventions resulted in no significant difference in age or gender distribution, length of hospital stay, critical care admission, helmet use, and mechanism of injury. There was a significantly higher proportion of severe injuries post interventions. **Conclusions:** Legislation and socialmarketing interventions had a short-term decrease on the frequency of ATV-related injuries and no sustained effect on the frequency, nature, and severity of ATV-related injuries. **Level of evidence:** Level IV

Keywords- About four key words or phrases in alphabetical order, separated by commas. Keywords are used to retrieve documents in an information system such as an online journal or a search engine. (Mention 4-5 keywords)

I. INTRODUCTION

Handling relates to the performance of the vehicle-operator system and the ease with which the operator can control and maneuver the vehicle so as to maintain the desired path and speed. In a handling evaluation, aspects of vehicle stability are also considered, namely, directional stability and lateral stability. Directional stability is included within the realm of handling as it relates to trajectory stabilization and ease of control during regular operation, when negotiating

irregular, sloped or rough terrains, or when experiencing changes in surface friction. It also includes the vehicle's inherent resistance to loss of directional control under aggressive maneuvering (i.e., plowing or spinning out during turning maneuvers and braking). Vehicle designers must choose a balance between directional stability and responsiveness. A heavily understeer stable vehicle may have difficulty negotiating around an obstacle whereas a highly responsive vehicle might not have good stability properties at high speeds. Lateral stability, in the context of a handling evaluation, is a vehicle's intrinsic resistance to side forces developed during cornering maneuvers that would cause the vehicle to tip or overturn. Lateral stability is also a consideration when evaluating off-road mobility specifically when negotiating very rough or sloped terrains. Vehicles such as ATVs, designed solely for off-road uses by a single operator, have different operational and performance requirements than do vehicles designed primarily for improved roadways – even SUVs such as Jeeps. For instance, off-road terrain negotiation is typically performed at lower speeds than what is common for on-road vehicles where freeway speed limits can be as much as 120 kph (75 mph). Off-road trail and dirt road widths are usually considerably less than the 3.7 m (12 ft) lanes for most roadways, and slopes occurring off-road can exceed 30 degrees whereas the steepest slope for automobiles in San Francisco, for example, is 17 degrees. Therefore, protocols for evaluating handling and stability of on-road vehicles may not be applicable for off-road vehicles, nor would the performance criteria be the same [1]. Because of the variety of surfaces, environmental conditions and terrains in which off-road vehicles such as ATVs are expected to operate – in conjunction with the important role of the operator for guidance, course selection and speed regulation, together with their rider-active character – the handling characteristics of off-road vehicles have historically been evaluated subjectively. This methodology allows for evaluators (test riders) to perceive the overall operator-vehicle handling qualities – both safety-related and performance-related – under a broad variety of operational, terrain and environmental conditions. Subjective testing is the only means to determine the driver's physical and mental efforts required to control the vehicle and thus establish ease of control especially when approaching the handling and stability limits

[2]. It also allows the rider to evaluate the quality of the feedback provided by the vehicle, which is essential for safe operation. As with any vehicle, the role of the operator is important for safe operation even in the most benign environments. Operators need to judge speed, path, and control inputs in relation to the existing terrain conditions (using both common sense and feedback cues available to him/her). However, it is expected that a vehicle produced for use by the general public exhibits a satisfactory level of handling and stability performance so that it does not place overly high demands on the driver for safe operation. In discussions by some researchers who are critical of the handling response of ATVs, much emphasis has been placed on the ATV's response in circle turn tests similar to that used by manufacturers of on-road passenger vehicles. These tests are designed to characterize those vehicles' steady-state cornering response. It has been suggested that ATVs, being a four-wheeled vehicle with a human operator, should have handling characteristics similar to those of passenger cars. However, because of their distinctly different missions, smaller size, operational environments (off-road surfaces versus primarily paved roads) and rider active nature, the optimal handling response of an ATV may be different from that of on-road passenger vehicles; and consequently, the premise that ATVs' handling should be judged based on passenger car standards has not been generally accepted by the ATV manufacturers. It should also be pointed out that tests like these are for measuring vehicle control properties and not handling, which involves the continuous interaction of the operator with the vehicle. Therefore, the attributes so derived only have value if they can be correlated with the opinion of a larger number of people to determine what characteristics give optimum handling and controllability [3].

II. LITERATURE REVIEW

Emily C. Benham et al, Patient demographics, behavior, and injury patterns were assessed to inform preventative efforts for reduced incidence of all-terrain vehicle (ATV) trauma. Methods: ATV-related injuries treated at a Level I trauma center from 2008 to 2012 were retrospectively reviewed. Patient outcomes and incidence of traumatic brain injury (TBI) were compared by helmet use and alcohol intoxication. Results: Helmet data were available for 304 patients of 404 patients included; of these, 75 (24.7%) wore a helmet. Incidence of TBI was lower in the helmeted (8.0%) versus the unhelmeted subgroup (26.6%) ($P < 0.001$). Helmeted patients had lower injury severity scores, lower intensive-care unit (ICU) admission rates, and shorter ICU and hospital length of stay (LOS) ($P < 0.05$). Intoxicated patients had higher rates of TBI and ICU admission as well as prolonged ICU LOS ($P < 0.05$). Conclusions: These data

support the requirement for a greater emphasis on injury prevention among ATV users.

Samuel Jessula et al, In 2004–2005, legislation restricting all-terrain vehicle (ATV) use by children and an extensive social marketing campaign intended to reduce pediatric ATV-related morbidity. The frequency, nature, and severity of pediatric ATV-associated trauma were compared before and after such interventions. Methods: A retrospective cohort study was performed for all pediatric ATV-related injuries that presented to the provincial level 1 pediatric trauma center from 1998 to 2014. National databases were queried for ATV-related injury hospitalizations ($n = 258$), trauma center emergency department visits ($n = 342$), and admissions ($n = 136$) in Nova Scotia from 2002 to 2014. Admissions between 1998 and 2003 ($n = 68$) and 2006–2014 ($n = 60$) were compared using chi square analysis for age and gender distribution, length of stay, critical care admission, helmet use, mechanism, and severity of injury. Results: Admissions, trauma center emergency room visits and admissions initially decreased following legislative and social marketing interventions and subsequently gradually increased. Interventions resulted in no significant difference in age or gender distribution, length of hospital stay, critical care admission, helmet use, and mechanism of injury. There was a significantly higher proportion of severe injuries post interventions. Conclusions: Legislation and socialmarketing interventions had a short-term decrease on the frequency of ATV-related injuries and no sustained effect on the frequency, nature, and severity of ATV-related injuries. Level of evidence: Level IV



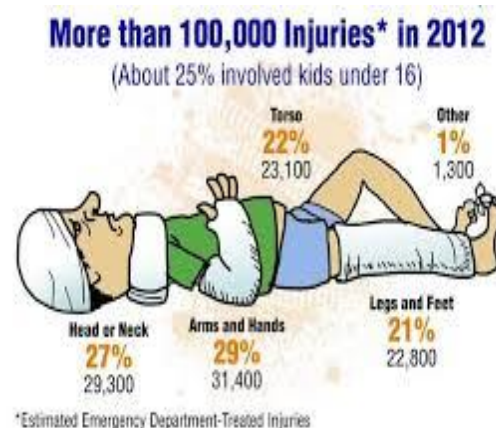
P. Moroney et al, All-terrain vehicles (ATVs) are fast, powerful machines that pose a significant threat to public safety. In the USA, ATVs are responsible for 273 deaths and over 68,000 injuries each year. As the incidence of ATV-related accidents in Britain and Ireland is unknown we carried out a prospective audit of all patients presenting to our Accident and Emergency Departments with ATV-related trauma over a 1-year period. Of 32 patients with ATV-associated injuries, 10 were under 16 years of age and 23 had no previous experience of operating an ATV. We documented

24 fractures (2 open) and 1 tension pneumothorax. Helmet usage was high and head injuries were few and not of a serious nature. Two-thirds of injuries occurred on commercial adventure sports courses. Since ATVs are off-road vehicles, they are exempt from safety regulations that apply to other forms of transport. As care-providers to trauma victims, we must make prevention of these injuries a priority and campaign for both voluntary and legislative controls to make ATV use a safer leisure pursuit.

Jeremy Schwark et al, The handling properties of All-Terrain Vehicles (ATVs) have been the subject of numerous investigations over the last two decades. Because the great majority of ATVs use a solid rear axle or a direct drive to both rear axles for improved off-road traction, these vehicles typically transition from understeer to oversteer with increased cornering severity in tests customarily used in the automobile industry to measure steady-state vehicle handling properties. An oversteer handling response is contrary to the accepted norm for on-road passenger vehicle handling and, for this reason, has drawn scrutiny from the Consumer Product Safety Commission (CPSC) staff and others. In the research described in this paper, an evaluation of ATV handling is presented in which 10 participants operated an ATV that was configured to have two different steady-state cornering characteristics. One configuration produced an approximately linear understeer response (labeled US) and the other configuration transitioned from understeer to oversteer (labeled US-OS) with increasing lateral acceleration in constant-radius turn tests. Participants found that the ATV with either the US or US-OS steady-state handling characteristic would be satisfactory for their typical use of an ATV; however, participants overwhelmingly preferred the US-OS Configuration. No participant reported that either configuration was unpredictable, although the ATVs were rated as more comfortable and received better steering feedback ratings for tight turns when configured to and operated in the US-OS Configuration as compared to the US Configuration. The objective data did not indicate that there was a control issue associated with the ATV configured to have an understeer /oversteer steady-state handling response. Course excursions were observed with both configurations, with the most significant occurring with the US-configured ATV. In summary, passenger car control response characteristics that have traditionally been found to be conducive to vehicle safety and control in that environment cannot be directly applied to the understanding of ATV safety and control.

III. DISCUSSION

ATV use is a significant cause of morbidity and mortality in both children and adults at rates that surpass those of other hazardous sports such as off-road motorcycling. Our study demonstrated an ATV-related mortality rate of 2.2%, which is similar to rates reported in the other large series (0.4e2.4%). Our study is one of the largest single-center series on ATV-related injuries and one of few that have included multivariate analyses to identify independent risk factors for adverse outcomes, specifically TBI. ATV related mortality was low in this population (9 patients) which did not allow for sufficient power to detect a statistical difference in helmet or intoxication status, or identify any other predictors for death. However, several prior studies cite helmet use as a protective factor against ATV-related injury; similarly, the current study identifies helmet use as the only protective factor against TBI. Additionally, helmet use was associated with increased presentation GCS, decreased ICU admission, hospital and ICU LOS, ISS, and rates of traumatic brain injury. There was also a non-significant trend toward increased rates to discharge home with the helmeted group, all of which highlight the need for helmet use in ATV users.

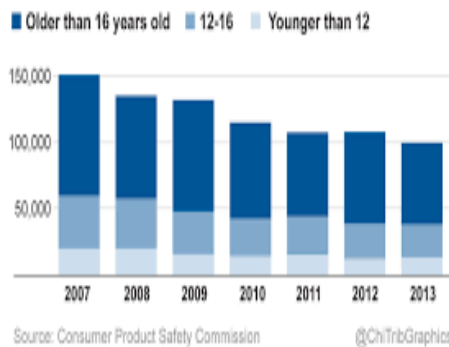


Our ATV injury demographics, including average age and gender distribution are similar to previous literature. Interestingly, our data show a subjective decrease in incidence of ATV-related injuries in the years immediately following the social marketing campaign and legislative change, associated with a decrease in ATV sales. This however is not sustained and rates of hospitalizations steadily climb thereafter. Our results echo the findings of Neiberg et al. who did not find a significant decrease in ATV-related traumatic injuries in children after similar legislative changes. Similarly, Beidler et al. studied patterns of ATV-associated injuries 6 months pre- and post-legislation change. Although they found statistically significant reduction in injuries in patients younger than 8, the results did not reach significance for ages

8–15, helmet use patterns and head injuries. These findings are contrasted with Helmkamp et al. which found significantly decrease death rates in ATV-related trauma in states with safety legislation. Helmkamp et al. study differs significantly from ours however in that they explored adult data and deaths only, whereas our study was specific to the pediatric population. Furthermore, their study compared different populations within the same time period as opposed to the same population pre- and post-intervention. A followup study demonstrated a three-fold increase in ATV-related mortality comparing 1990–1998 vs. 2000–2007 in the US. Although some regulations were introduced in between both time periods, these were not uniformly adopted across all states. Furthermore, ATV sales dramatically increased across both time periods. Helmet use patterns did not change across our timelines. Keenan et al. compared states with and without mandatory helmet legislation and found increase helmet use in ATV users with associated legislation. It should be noted however that the change in legislation did not affect the regulations of helmets when operating an ATV, which have always been mandatory in Nova Scotia. In the pediatric bicycling realm, helmet legislation has led to increased helmet use and decreased injury and mortality.

ATV injuries by age

Estimated injuries treated at emergency rooms



Although ATVs are marketed for their ability to negotiate rough ground and adverse weather conditions, their design makes them inherently unstable machines. ‘Three-wheelers’ were banned for safety reasons in 1988 and replaced by four-wheeled ‘Quad bikes’. Yet these are also prone to overturn on a steep gradient or on uneven ground. With a seat height of ~80 cm, ATVs have a high centre of gravity. Their weight and speed demand skill, strength, co-ordination and maturity. As all-terrain vehicles are designed for ‘off-road’ use, they do not require a driving licence. In Ireland, they are classified as tractors, mopeds or ‘motor tricycles’ depending on weight. Therefore, there is no single regulatory body responsible for their safe use. The National Roads Authority

that compiles annual morbidity and mortality figures for Irish roads does not record ATV-related injuries. Several authors have previously documented the risks of ATV use. In 1986, Doyle Haynes et al. detailed the mechanics of ATV instability. Subsequently, major alterations were made to ATV design that significantly improved their safety profile. In 1988, all ATV manufacturers in the USA signed legally binding ‘Consent Decrees’ that outlawed the sale of three-wheeled all-terrain vehicles and banned the sale of adult-sized all-terrain vehicles to children less than 16 years of age. Free training courses and safety information had to be provided by all retailers. These agreements, however, have no legal standing outside the USA.

This study has identified recreational ATV usage as a significant health hazard in Ireland. Mechanism of injury data and age profiles were similar to those in other published series. As expected, orthopaedic injuries predominated, however, in our group of patients there were only two minor head injuries. This contrasts starkly with the experience of other authors. Lister et al. reported a 40.8% incidence of head injuries in a retrospective review of paediatric ATV-related trauma in west Virginia. A low level of helmet usage has been a risk factor in previous publications and has been associated with increased mortality. That 78% of our patients wore helmets reflects the different practices in ATV use in Ireland. Despite a recent growth in sales of ATVs to private individuals, the majority of those who drive and sustain injuries from ATVs do not own or regularly use one. Sixty-six percent of patients in our study were injured on supervised commercial courses, where the wearing of helmets was compulsory.

Seventy-two percent of our patients were complete beginners who had no previous ATV driving experience. Such novices require careful training from qualified instructors on level driving surfaces before they tackle the turns and steep gradients that are found on many commercial courses. Provision of helmets alone does not constitute safe practice.

As the prosperity of any society grows, the time and money that is spent on leisure activities increase. Thus, ATV usage and morbidity as documented in this study are likely to grow in parallel over the next decade. This small study highlights the considerable morbidity associated with ATV usage. With lower levels of private ownership here than in the USA, access to ATVs still exists in a limited and potentially controllable environment. The experience from North America indicates that we must institute sensible safety regulations urgently in an attempt to curb further ATV-related trauma.

IV. CONCLUSION

ATV trauma yields substantial patient morbidity and mortality, especially when combined with alcohol and lack of helmet use. Despite state laws requiring helmet use, compliance remains low, particularly among intoxicated ATV users. Heightened awareness of these issues regarding helmet use and alcohol intoxication among ATV users may focus future initiatives to reduce ATV-induced traumatic injury, such as more stringent legislation enforcement and community-based educational programs. In sum, participants in the study found that the ATV with either the US or US-OS steady-state handling characteristic would be satisfactory for what they used an ATV for, but participants overwhelmingly preferred the US-OS Configuration, with higher ratings in comfort operating the ATV and steering feedback in tight, slow turns for the US-OS Configuration. The results reported in this paper show that ATVs with both a limit understeer and a limit oversteer steering response can be operated safely when used in a reasonable manner. It is expected that manufacturers would choose an appropriate handling balance for their vehicle based on its anticipated use and consideration of performance characteristics such as throttle response and maximum speed.

The use of ORVs can be dangerous, as reflected by the fatality and serious injury data described in this paper. Of great concern, alcohol seems to be an important factor that contributes to this problem. Also, the data suggest that youth under the age of 16 are prone to serious injuries when driving ORVs or riding along as passengers. While some progress has been made with respect to snowmobiles, the same is not true of ATVs and dirt bikes as evidenced by an increasing fatality rate. Changing behavior may be particularly challenging with this group given that most of the crashes occur off the public roads, where adhering to traffic rules and safety procedures may be less salient in the operator's mind. The often recreational nature of ORV use can obfuscate the more dangerous aspects of these vehicles. Measures are required to mitigate the risks of ORV use. These mitigation efforts may include public awareness campaigns designed to draw attention to the issues of child injuries among ORV users, and of the prevalence of alcohol use among older operators.

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