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ORIGINAL ARTICLE

Alcohol is a risk factor for helmet non-use and fatalities in off-road vehicle and motorcycle crashes

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Abstract

Objectives Off-road vehicle (ORV) and motorcycle use is common in Canada; however, risk of serious injury is heightened when these vehicles are operated without helmets and under the influence of alcohol. This study evaluated the impact of alcohol intoxication on helmet non-use and mortality among ORV and motorcycle crashes.

Methods Using data collected from the Nova Scotia Trauma Registry, a retrospective analysis (2002–2017) of ORV and motorcycle crashes resulting in major traumatic brain injury was performed. Patients were grouped by blood alcohol concentration (BAC) as negative (< 2 mmol/L), legally intoxicated (2-17.3 mmol/L) or criminally intoxicated (> 17.3 mmol/L). Logistic regression models were constructed to test for helmet non-use and mortality.

Results A total of 424 trauma patients were included in the analysis (220 ORV, 204 motorcycle). Less than half (45%) of patients involved in ORV crashes were wearing helmets and 65% were criminally intoxicated. Most patients involved in motorcycle crashes were helmeted at time of injury (88.7%) and 18% were criminally intoxicated. Those with criminal levels of intoxication had 3.7 times the odds of being unhelmeted and were 3 times more likely to die prehospital compared to BAC negative patients. There were significantly increased odds of in-hospital mortality among those with both legal (OR = 5.63), and criminal intoxication levels (OR = 4.97) compared to patients who were BAC negative.

Conclusion Alcohol intoxication is more frequently observed in ORV versus motorcycle crashes. Criminal intoxication is associated with helmet non-use. Any level of intoxication is a predictor of increased in-hospital mortality.

Keywords Traumatic brain injury · Off-road vehicles · All-terrain vehicles · Motorcycles · Alcohol · Mortality

Introduction

Motorcycles and off-road vehicles (ORVs) such as all-terrain vehicles (ATVs), side-by-sides (SxSs), utility terrain vehicles (UTVs), and snowmobiles are commonly used for transportation, work, and recreation in Canada. Each year, there are approximately 180 motorcycle fatalities [1], 100 ATV fatalities [2], and 73 snowmobile fatalities across the country [3]. In Nova Scotia, motorcycles and ORVs are popular for both recreation and transportation/work purposes. Previous studies in Nova Scotia have shown that ATV injuries in children closely resemble injuries from motor vehicle collisions (MVCs) [4]. Legislation restricting ATV use by children led to a short-term decrease but no sustained effect on the frequency and severity of ATV injuries [5]. The risk of injury while operating these vehicles is heightened by numerous factors including driving unhelmeted, night driving, having multiple passengers, engaging in risky behavior (e.g., jumps, high speeds), and use of alcohol and/or drugs [6–8]. Use of alcohol/drugs has been reported in roughly half of ATV and snowmobile deaths [2, 3], and in nearly one third of motorcycle fatalities [9].

Traumatic brain injury (TBI) is the primary cause of death from motorcycle and ORV crashes [10, 11]. While some ORVs have safety features like seat belts and roll

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cages, helmets remain the best form of head protection and are associated with significantly lower risk of TBI and death among riders involved in a crash [12, 13]. At least one-third of ATV fatalities in Canada involve unhelmeted riders [2]. Furthermore, there is evidence that use of alcohol/drugs is associated with increased odds of not wearing a helmet among those injured in motorcycle crashes [14] and ATV crashes [15]. The aim of this study was to assess the demographic and injury patterns of patients presenting with ORV- or motorcycle-related TBI to a Level I trauma centre. Specifically, we hypothesized that crashes involving alcohol are associated with increased risk of not wearing a protective helmet, as well as increased odds of prehospital and in-hospital mortality.

Methods

Study design and time period

This was a retrospective cohort study of major TBI patients injured between January 2002 and December 2017. Study data were collected from the Nova Scotia Trauma Registry (NSTR). The NSTR is a provincial population-based registry under the Nova Scotia Department of Health and Wellness and contains data on all major trauma patients with an Injury Severity Score (ISS) ≥ 12 and an appropriate International Statistical Classification of Diseases and Related Health Problems, Tenth Revision, Canada (ICD-10-CA) code. The NSTR also includes penetrating traumas with an ISS ≥ 9 or greater, all trauma team activations (TTAs) regardless of ISS, and traumas resulting in death prior to hospital arrival or in the ED. This study was performed in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for reporting observational studies [16].

Study setting

All major trauma and adult neurosurgical services in the Nova Scotia are centralized at the Queen Elizabeth II Health Sciences Centre (QEII HSC) in Halifax. This centre services a population of 938,183 within 55,000 km^2 and receives all major neurotrauma cases from within the province as well as some cases from Prince Edward Island.

Population

We included all major TBI patients injured in an ORV or motorcycle crash during the study period. Consistent with the literature, major TBI was defined using the maximal Abbreviated Injury Scale (AIS) Head score [17, 18] and ICD-10-CA injury codes. All patients in the NSTR with a maximum AIS Head score ≥ 3 and a primary ICD-10-CA diagnosis code consistent with blunt or penetrating trauma were included. For this study, ORVs included ATVs, UTVs, SxSs, and snowmobiles.

Data collection

Data elements collected from the NSTR included age, sex, injury mechanism, use of helmet, maximum AIS Head score, ISS, Glasgow Coma Scale (GCS) score, TTA, blood alcohol concentration (BAC) testing, BAC level, and discharge status. Quantitative alcohol levels were determined during the initial ED visit or by post-mortem testing by the Nova Scotia Medical Examiner Service. BAC levels are reported as millimoles of ethanol per liter of blood (mmol/L).

When a patient dies at the crash scene or before admittance to hospital, law enforcement or emergency medical personnel notify the provincial Medical Examiner who draws a blood sample and conducts a BAC test from fatal crashes. Because post-mortem blood presents problems due to variable conditions and changes to concentrations from one place to another in the body after death, the Medical Examiner commonly analyzes vitreous humor for BAC. A BAC level of 0-1.9 mmol/L was coded as BAC negative (as defined by the National Trauma Registry); any BAC reported as ≥ 2mmol/L was considered positive. Positive BAC levels were further categorized as legal intoxication (2-17.3mmol/L) or criminal intoxication (> 17.3mmol/L). Throughout Canada, the maximum legal BAC for fully licensed drivers is < 80 mg alcohol in 100 ml of blood, or 0.08 gram% (0.08 g alcohol/100 ml = 17.3 mmol/L). Driving with a BAC of 17.3 mmol/L or higher is a criminal offence.

Outcome measures

Outcome measures included helmet non-use and mortality (prehospital, in-hospital). Prehospital mortality was defined as death at the scene or during transfer to hospital, while in-hospital mortality was defined as death occurring at any time after arrival to an ED.

Data analysis

Demographic and injury characteristics were described using means ± standard deviations for continuous variables and counts and percentages for categorical variables. Between groups comparisons were performed with a chi-square (categorical data) and with Student's t-test or one-way ANOVA test (continuous data), as appropriate, with the following BAC levels: negative (BAC 0-1.9 mmol/L),

Table 1 Characteristics of patients injured in ORV and motorcycle crashes in Nova Scotia, 2002–2015

Characteristic	ORV trauma ($n=220$)	Motorcycle trauma ($n=204$)	p-value
Age, mean ± SD	34 ± 15.5	44 ± 15.2	< 0.001
Male sex, n (%)	199 (90.5)	181 (87.7)	0.63
Helmet use, n (%)	99 (45.0)	181 (88.7)	< 0.001
GCS on ED arrival, mean ± SD	10.9 ± 5.2	11.0 ± 4.9	0.53
Max AIS Head, mean ± SD	4.0 ± 0.8	4.0 ± 0.9	0.62
ISS, mean ± SD	27.7 ± 14.2	36.6 ± 19.0	< 0.001
TTA, n (%)	115 (52.3)	94 (46.1)	0.20
BAC testing performed, n (%)	146 (66.4)	140 (68.6)	0.62
BAC level, n (%)			
Negative (0-1.9 mmol/L)	37 (25.3)	107 (76.4)	< 0.001
Legal intoxication (2-17.3mmol/L)	14 (9.6)	8 (5.7)	
Criminal intoxication (> 17.3mmol/L)	95 (65.1)	25 (17.9)	
Mortality, n (%)			
Prehospital	35 (17.9)	50 (29.2)	0.01
In-hospital	23 (12.5)	31 (20.4)	0.05

ORV off-road vehicle; *TBI* traumatic brain injury; *GCS* Glasgow Coma Scale; *AIS* Abbreviated Injury Score; *ISS* Injury Severity Score; *BAC* blood alcohol concentration; *TTA* Trauma Team Activation

Table 2 Characteristics of patients by blood alcohol concentration

Characteristic	BAC Negative ($n=144$)	Legal Intoxication ($n=22$)	Criminal Intoxication ($n=120$)	p-value
Age, mean ± SD	41 ± 15.2	28 ± 8.5	37 ± 12.7	< 0.001
Male sex, n (%)	127 (88.2)	17 (77.3)	113 (94.2)	0.035
Vehicle type, n (%)				
ORV	37 (25.7)	14 (63.6)	95 (79.2)	< 0.001
Motorcycle	107 (74.3)	8 (36.4)	25 (20.8)	
Helmet use, n (%)	115 (79.9)	17 (77.3)	60 (50.0)	< 0.001
GCS on ED arrival, mean ± SD	10.5 ± 5.2	12.4 ± 4.4	8.9 ± 5.4	0.20
Max AIS Head, mean ± SD	4.1 ± 0.9	4.1 ± 0.9	3.9 ± 0.9	0.37
ISS, mean ± SD	35.5 ± 18.3	35.9 ± 17.9	29.6 ± 16.3	0.02
TTA, n (%)	87 (60.4)	13 (59.1)	69 (57.5)	0.89
Mortality, n (%)				
Prehospital	33 (26.4)	5 (27.8)	33 (32.0)	0.64
In-hospital	16 (14.8)	4 (23.5)	17 (19.5)	0.54

ORV off-road vehicle; *GCS* Glasgow Coma Scale; *AIS* Abbreviated Injury Score; *ISS* Injury Severity Score; *BAC* blood alcohol concentration; *TTA* Trauma Team Activation; *BAC Negative* BAC 0-1.9 mmol/L; *Legal Intoxication* BAC 2-17.3 mmol/L; *Criminal Intoxication* BAC > 17.3 mmol/L

legal intoxication (2-17.3 mmol/L), and criminal intoxication (> 17.3 mmol/L). An age and sex-adjusted regression model for the association of BAC with helmet use was created. Prehospital and in-hospital mortality were modelled with multivariate logistic regression using age, AIS Head, ISS, and BAC levels as covariates. We did not include sex in the multivariate logistic regression modeling given that the vast majority of the study sample were males. The resulting coefficients were exponentiated to obtain adjusted odds ratios (ORs). A p-value less than 0.05 was considered statistically significant. ORs were reported with 95% confidence intervals (CIs). All data were analyzed using SPSS software (version 27; SPSS Inc., Chicago) and R Statistical Software (version 4.2.5).

Ethics Approval

All study procedures were approved by the institutional research board (File #1018117).

Results

A total of 5590 major TBI patients were seen in Nova Scotia during the 16-year study period. Of these, 220 patients were ORV drivers and 204 were motorcycle drivers. Characteristics of TBI patients injured in ORV and motorcycle crashes are compared in Table 1. Patients injured in ORV crashes were younger (34 ± 15.5 vs. 44 ± 15.2, $p < 0.001$) and had lower mean ISS scores (27.7 ± 14.2 vs. 36.6 ± 19.0, $p < 0.001$) than those injured in motorcycle crashes. Less than half (45%) of patients injured in ORV crashes were wearing helmets compared with 89% of motorcycle crashes ($p < 0.001$). BAC testing was performed in 66% (146/220) of ORV crashes and 68% (138/204) of motorcycle collisions. BAC levels were significantly different between ORV and motorcycle crashes. Prehospital mortality was observed in 20% (85/424) of the study sample; the proportion of prehospital mortality was significantly greater than motorcycle crashes (29% vs. 18%, $p = 0.01$).

Characteristics of patients injured in ORV or motorcycle crashes were compared by BAC level (Table 2). Helmet use was highest in BAC negative patients (80%, 115/144) and least frequent in drivers with criminal BAC levels (50%, 60/120). Mean ISS was statistically different between the three BAC categories, with the most severe injuries observed in the BAC negative group (mean ISS 35.5 ± 18.3) and the least severe injuries in the criminally intoxicated BAC group (mean ISS 29.6 ± 16.3).

To determine whether alcohol intoxication predicted helmet non-use in ORV and motorcycle drivers, two separate regression models were implemented, one for all crashes and one for fatal crashes (Table 3). After adjustment for age and sex, those with criminal BAC (> 17.3 mmol/L) had 3.7

Table 3 Factors associated with helmet non-use among all crashes and fatal crashes

Variable	All Crashes			Fatal Crashes		
	Adjusted OR	95% CI	*p*-value	Adjusted OR	95% CI	*p*-value
Age	0.98	0.96-1.00	0.06	0.96	0.92–0.99	0.029
Male sex	0.99	0.40–2.45	0.99	0.59	0.12–2.84	0.51
BAC level						
Negative	Reference	-	-	Reference	-	-
Legal intoxication	0.93	0.31–2.81	0.89	0.42	0.04–4.64	0.48
Criminal intoxication	3.77	2.17–6.52	< 0.001	3.94	1.37–11.34	0.011

BAC blood alcohol concentration; *OR* odds ratio; *CI* confidence interval; *BAC Negative* BAC 0-1.9 mmol/L; *Legal Intoxication* BAC 2-17.3 mmol/L; *Criminal Intoxication* BAC > 17.3 mmol/L

Table 4 Factors associated with prehospital and in-hospital mortality

Variable	Prehospital Mortality			In-hospital Mortality		
	Adjusted OR	95% CI	*p*-value	Adjusted OR	95% CI	*p*-value
Age	1.00	0.99–1.04	0.21	1.05	1.02–1.09	0.002
Helmet use	2.47	1.12–5.46	0.03	2.06	0.77–5.54	0.15
Max AIS Head score	1.15	0.72–1.84	0.55	3.86	1.91–7.81	< 0.001
ISS	1.07	1.04–1.09	< 0.001	1.05	1.01–1.08	0.020
BAC level						
Negative	Reference	-	-	Reference	-	-
Legal intoxication	1.31	0.34–4.95	0.69	5.63	1.19–26.59	0.029
Criminal intoxication	3.12	1.48–6.55	0.003	4.97	1.81–13.67	0.002

OR odds ratio; *CI* confidence interval; *AIS* Abbreviated Injury Score; *ISS* Injury Severity Score; *TTA* Trauma Team Activation; *BAC* blood alcohol concentration; *ORV* off-road vehicle; *BAC Negative* BAC 0-1.9 mmol/L; *Legal Intoxication* BAC 2-17.3 mmol/L; *Criminal Intoxication* BAC > 17.3 mmol/L

times the odds of being unhelmeted at the time of injury ($p < 0.001$). Similarly, among fatal crashes, criminal intoxication was associated with nearly 4 times the odds of being unhelmeted at the time of the ORV or motorcycle crash (OR 3.9, $p = 0.01$).

Multivariable logistic regression models were created to assess for factors associated with prehospital and in-hospital mortality (Table 4) where age, helmet use, maximum AIS Head score, ISS, and BAC levels were included as predictors. Prehospital mortality was associated with increasing ISS (OR 1.07, 95% CI 1.03–1.07) and patients with criminal intoxication were 3 times more likely to die in the pre-hospital setting than BAC negative patients. Variables positively associated with the odds of in-hospital mortality were age (OR 1.05, 95% CI 1.02–1.09), maximum AIS Head score (OR 3.86, 95% CI 1.91–7.81) and ISS (OR 1.05, 95% CI 1.01–1.08). Compared with BAC negative drivers, drivers with legal intoxication had over five times the odds of experiencing in-hospital mortality (OR 5.63 95% CI 1.19–26.59), while drivers with criminal intoxication had 5 times the odds of experiencing in-hospital mortality (OR 4.97 95% CI 1.81–13.67).

Discussion

This population-based study reports on the demographics and injury patterns of ORV and motorcycle-related TBI in Nova Scotia. Alcohol intoxication was found to be a pervasive risk factor for helmet non-use and mortality. Nearly three quarters of those involved in ORV crashes tested positive for BAC. Patients with BAC levels above 17.3 mmol/L had nearly 4 times the odds of helmet non-use compared with those who were BAC negative. The study findings underscore the critical role of alcohol intoxication with mortality resulting from ORV and motorcycle collisions; in the prehospital setting, BAC levels above 17.3 mmol/L independently predict prehospital mortality, while both legal and criminal levels of intoxication are linked to a five-fold increase in the odds of in-hospital mortality.

We observed that helmets were only worn by 50% of the patients in this criminally intoxicated BAC high group, but both ISS and maximum AIS Head were not significantly different among patients in the three BAC categories. While it may be expected that the absence of helmet usage would correlate with higher injury severity scores, our findings do not align with this expectation. Several factors may contribute to this unexpected observation. Firstly, the effectiveness of helmets in preventing head injuries can vary depending on various factors such as helmet design, fit, and the type and severity of the impact. Secondly, the circumstances

surrounding the incidents, including the speed of the vehicles involved, the angle of impact, and other environmental factors, can significantly influence the resulting injury severity regardless of helmet usage. We did not assess isolated versus multiple trauma in the study cohort which may also be an important consideration for injury severity.

There are conflicting studies of the effect of alcohol on trauma mortality, with evidence that alcohol both decreases [17–21] and increases [15, 22–24] mortality rates. Once a traumatic injury occurs, alcohol intoxication may paradoxically improve survival outcomes in certain cases, possibly due to physiological factors like decreased pain perception, relaxed muscles, or altered inflammatory response. While these studies indicate a potential protective effect of alcohol on mortality in trauma patients, the authors acknowledge the need for further research to elucidate the nature of this relationship and the underlying mechanisms involved. Of note, there appears to be a discrepancy in the cut-offs of BAC defined by the different studies when examining the potential protective effects of alcohol intoxication on injury severity and mortality. Additionally, the relationship between alcohol consumption and outcomes in trauma patients is influenced by a range of factors including post-injury interval, injury severity, prior drinking patterns, and day of injury alcohol use, yet several of these variables are not included as covariates in observational studies. Therefore, while many studies raise intriguing questions about the potential protective effects of alcohol in trauma patients, their limitations underscore the need for more rigorous, prospective, and controlled research to better understand this complex relationship and its underlying mechanisms [25–27].

Results from the current study align with previous findings that alcohol is a risk factor in crashes involving ATVs [2, 24, 28, 34], snowmobiles [9, 28] and recreational watercraft [29]. Helmet use has been shown to be effective in reducing TBIs due to motorcycle and ORV crashes [10, 11]. ATV riders who do not wear helmets are more likely to receive significant injuries to the head, face, and neck [12]. Our results demonstrate that alcohol intoxication is a significant risk factor for both helmet non-use and mortality among ORV and motorcycle collisions. We found that helmet use among ORV crashes was just under 50% and that alcohol use decreased the likelihood of helmet use. A study from Newfoundland and Labrador reported similar results in their local study population [30].

Previous investigations have consistently shown a higher incidence of in-hospital mortality among motorcycle crash patients with elevated blood alcohol concentration compared to those who test negative [31, 32]. A similar association exits between alcohol intoxication and ORV fatalities; in over half of ATV-related fatalities from 2013 to 2019, the drivers had consumed alcohol, cannabis or other drugs [2]. Our study findings are consistent with the current literature. Specifically, prehospital mortality was observed in 20% of patients in our study. Patients with criminal BAC levels (> 17.3 mmol/L) had more than triple the risk of prehospital mortality after adjusting for helmet use, age, and injury severity. Drivers with any level of alcohol intoxication had over five times the risk of in-hospital mortality compared with BAC negative drivers.

Strengths and limitations

Our findings are subject to the known limitations of retrospective data analysis and cannot be used to imply causality. Although data were collected from a robust prospective population-based registry, information was unknown or incomplete in some cases. Importantly, a large number of patients were not tested for alcohol use. Furthermore, this study was focused on a major TBI population treated at a single centre; thus, our results may not be generalizable to other patient populations.

Clinical implications

Our findings underscore the significance of alcohol intoxication as a prevalent and independent risk factor associated with both helmet non-use and mortality in ORV and motorcycle crashes. It is imperative for frontline emergency providers and policymakers to recognize the widespread involvement of alcohol in these incidents, prompting the necessity for alcohol screening among crash-involved patients. This awareness can equip clinicians to engage patients in crucial injury prevention discussions. Additionally, studies advocate for the role of EDs in evaluating and referring at-risk patients to substance use disorder programs [33]. Implementing screening programs and establishing efficient referral pathways can effectively connect patients with the necessary resources and support to prevent the morbidity and mortality consequences of alcohol intoxication in ORV and motorcycle crashes.

Research implications

Nova Scotians aged 16 years and older must complete a safety training program in order to legally operate an ORV and all drivers are required to wear an approved helmet. Although helmets are legally required for wheeled activities in Nova Scotia, there are challenges with enforcing this legislation, especially in rural areas, and there is limited information available on compliance with this law among ORV riders. Further research is required to understand the factors associated with alcohol misuse in this population which can

then serve as a target to reduce injury through legislation and community-based education programs [6].

Conclusions

Our findings demonstrate that three quarters of TBI patients injured in ORV crashes were positive for blood alcohol. Less than half of patients involved in ORV crashes were wearing helmets, while helmet compliance was higher among motorcyclists. Alcohol intoxication is a significant risk factor for prehospital and in hospital mortality in ORV and motorcycle-related TBI.

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Author contributions N.K, D.B.C, M.E., and R.G were involved in the conceptualization, methodology, analysis, and writing. S.W and I.O were involved in the methodology, analysis, and writing. All authors reviewed the final manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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