Journal of Safety Research 59 (2016) 23–31

Contents lists available at ScienceDirect

Journal of Safety Research

journal homepage: www.elsevier.com/locate/jsr

Understanding risk factor patterns in ATV fatalities: A recursive partitioning approach

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ARTICLE INFO

Article history:
Received 19 May 2016
Received in revised form 23 August 2016
Accepted 5 October 2016
Available online 15 October 2016

Keywords:
ATV
All-terrain vehicle
Risk factors
Epidemiologic triangle
Helmet use

ABSTRACT

Introduction: Although there are hundreds of ATV-related deaths each year in the United States, contributing factors have not been clearly identified. The purpose of this study was to investigate associations between factors contributing to ATV fatalities using the agent–host–environment epidemiological triangle. *Method:* Incident reports of ATV fatalities occurring between 2011 and 2013 were obtained from the United States Consumer Product Safety Commission (CPSC). Narrative reports included details of the decedent and a description of the ATV crash. A chi-square automatic interaction detector (CHAID) analysis was performed for three major risk factors representing each facet of the epidemiologic triangle: helmet use (host), type of crash (agent), and location where death occurred (environment). The output of the CHAID analysis is a classification tree that models the relationship between the predictor variables and a single outcome variable. *Results:* A total of 1193 ATV fatalities were reported to the CPSC during the 3-year study period. In cases with known helmet and/or drug and alcohol use status, descriptive statistics indicated helmets were not worn in 88% of fatalities and use of alcohol or drugs was present in 84% of fatalities. Reoccurring factors within the CHAID analysis included age, helmet use, geographic region of the country, and location (e.g., farm, street, home, etc.) at the time of death. Within the three CHAID models, there were seven significant partitions related to host, one related to agent, and eight related to the environment. *Conclusions:* This research provides a model for understanding the relationship between risk factors and fatalities. The combination of the CHAID analysis method and the epidemiologic triangle allows for visualization of the interaction between host–agent–environment factors and fatalities. *Practical applications:* By modeling and characterizing risk factors associated with ATV fatalities, future work can focus on developing solutions targeted to specific factions of ATV users.

1. Introduction

All-terrain vehicles (ATVs) were marketed in the United States in the 1970s as an occupational tool that bridged the gap between the tractor and horse (Balthrop, Nyland, & Roberts, 2009). While ATVs are still used for occupational purposes, there has been a substantial amount of growth in the number of recreational riders in the United States. In 1990, there were an estimated 1.8 million ATVs in use in the United States (Topping & Garland, 2014); in 2011, this number rose to 10.7 million (Topping & Garland, 2014). According to the United States Consumer Product Safety Commission (CPSC), the estimated number of four-wheeled ATV-related injuries in 1990 was 30,800 and the estimated number of deaths was 152 (Topping & Garland, 2014). In 2011, these numbers rose to 105,000 injuries and 666 deaths (Topping & Garland, 2014), a 241% and 338% increase, respectively.

Injury prevention strategies focused on the reduction in ATV-related injuries and fatalities must address the various risk factors associated with these incidents. The epidemiologic triangle has been a useful model to better understand the complexity of risk factors contributing to injuries and fatalities (Hulme & Finch, 2015; Runyan, 2003). Risk factors for ATV fatalities can be categorized to fit the three elements of the Epidemiologic Triangle: host, agent, and environment.

Host factors relate to the demographics or behaviors of the ATV operator such as gender (Breslau, Stranges, Gladden, & Wong, 2009; Goldcamp, Myers, Hendricks, Layne, & Helmkamp, 2006; Helmkamp, Aitken, & Lawrence, 2009; O'Connor, Hanks, & Steinhardt, 2009; Rechnitzer, Grzebieta, McIntosh, & Simmons, 2013; Rodgers, 2008; Rodgers & Adler, 2001), age (Balthrop et al., 2009; Helmkamp & Carter, 2009; Helmkamp, Marsh, & Aitken, 2011; O'Connor et al., 2009; Rodgers, 2008; Rodgers & Adler, 2001), experience and training

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http://dx.doi.org/10.1016/j.jsr.2016.10.004
0022-4375/

(Goldcamp et al., 2006; O'Connor et al., 2009; Rodgers & Adler, 2001), use of personal protective equipment(Fleming, 2010; Mangus, Simons, Jacobson, Streib, & Gomez, 2004; Myers, Cole, & Mazur, 2009), risk tolerance and perception of the operator (Fleming, 2010), and use of drugs and alcohol (Fleming, 2010). Agent factors are those that relate to the energy of the ATV. This includes speed capabilities (Helmkamp et al., 2011), the stability and weight of the vehicle (Percy & Duffey, 1989), and mechanical failures (Fleming, 2010). Environmental factors include both the physical and social environment. While many of the environmental risk factors associated with ATV fatalities are controllable, such as the road surface (off-road vs. asphalt), others, such as weather, are not easily controlled. Factors related to the social environment include behaviors associated with group riding and ATV operation with passengers (Fleming, 2010).

Using the epidemiologic triangle as a classification method for understanding underlying risk factors for fatalities may lead to safety and protection innovations. Identification of the predominant risk factor classification, host, agent, or environment, will help direct resources to the appropriate intervention strategy, whether that be legislation, engineering controls, advances in the effectiveness or use of personal protective equipment, or operator training. The Haddon Matrix is a method of examining possible interventions to the different aspects of the epidemiologic triangle at different points in the accident timeline (Haddon, 1968). Haddon stated, "There are essentially three major portions or phases of the sequence of events leading up to the end results, during which causal factors are active and countermeasures can be undertaken" (Haddon, 1968). Haddon originally called these phases "the phases of social concern." In most applications, these phases would later be simplified to correspond to the pre-accident, accident, and post-accident phase of the injury event (Haddon, 1968). Application of the Haddon Matrix allows for evaluation of the hazards of the accident, as well as identification of a set of solutions that could be applied to risks associated with that injury event.

To date, the preponderance of intervention strategies designed to reduce the high injury rate associated with ATVs have targeted host and agent risk factors rather than environmental factors. In 1988, the CPSC proposed a 10-year plan to increase ATV safety by prohibiting the sale of three-wheeled ATVs, establishing age recommendations for ATV operators, and implementing training programs for new ATV purchasers (Rodgers & Adler, 2001). This plan was successful in reducing ATV-related fatalities. In 1988, the estimated rate of ATV-related fatalities in the United States was 179 per million ATVs in use (Topping & Garland, 2014). By 1998, the estimated ATV fatality rate had declined to 81 per million ATVs in use (Topping & Garland, 2014). However, just one year after the plan's expiration, in 1999, the fatality rate rose to 105 per million ATVs in use (Topping & Garland, 2014).

Due to the success of the CPSC's initial safety campaign, and the increasing injury and fatality rates after its expiration (Balthrop et al., 2009), the CPSC enacted the 2008 Consumer Product Safety Improvement Act (CPSIA). This act was designed to increase the safety of the ATV and reduce the fatality rate by altering design, promoting awareness of safe ATV operation through training and marketing, and targeting a high-risk age demographic of users, children and youth.

Similar to the 1988 plan, the 2008 CPSIA was designed to combat the increasing ATV fatality rate from the host and agent aspects of the epidemiologic triangle. The 2008 CPSIA's campaign intended to reduce the risk to children and youth by recommending smaller engine sizes and a maximum speed based on the child's age (Catenacci, 2009; Fleming, 2010; Goldcamp et al., 2006). Agent-related risk factors were further controlled by extending the ban on the sale of three wheeled ATVs. While this mandatory design change from three to four wheeled vehicles increased the stability and balance of the ATV (Percy & Duffey, 1989), a literature review (Balthrop et al., 2009) suggested that factors related to the social environment, consumer culture and demand, drove the industry to increase the speed and power of ATVs. The increase in ATV power may have offset the benefits of improved design and resulted in increased severity of ATV injuries (Balthrop et al., 2009). The interaction between agent and environmental factors demonstrates the complexity of developing and implementing intervention strategies for improving ATV safety.

The purpose of this study was to examine and model contributing factors of ATV injuries and fatalities using three years of CPSC fatality reports. The Epidemiological Triangle was used to model the complexity of factors associated with ATV-related fatalities. Use of the epidemiologic triangle allows for an improved understanding of the different sources of risk and the interaction between the operator, machine and environmental conditions.

2. Methods

2.1. Data source

ATV incident data were obtained from CPSC In-Depth Investigation Files (INDP) for the years 2011–2013. The INDP files are reports of incidents and fatalities that have been investigated by the CPSC based on interviews or on-scene investigations. Each INDP report contains demographic information as well as a narrative report of the incident. The CPSC identifies incidents for investigation from a variety of different sources, the main sources being: news reports, death certificate files (DTHS), and the Medical Examiners and Coroners Alert Project (MECAP). Once identified, these incidents are investigated by CPSC personnel either by phone, onsite, or using other methods.

2.2. Data collection

Each INDP report was read and manually coded into a Microsoft Excel File. The internal reliability of the coding was checked using two different coders. One coder entered the data from all fatality reports while a second coder entered data from a randomly selected sample of 10% of reports. The reliability between the two coders was analyzed for each variable using Cohen's Kappa. Kappa values of 0.81 or higher were considered to have excellent agreement (Landis & Koch, 1977).

To apply the epidemiological triangle to each case, variables from the demographic and narrative sections of the INDP reports were categorized as pertaining either to the agent, the host, or the environment. Variables pertaining to the host (ATV user) involved in the crash included: age, sex, status as the driver or passenger of the ATV, helmet use (yes, no, unknown), and use of alcohol or drugs (yes, no, unknown). Variables pertaining to the agent (the energy of the ATV) involved in the crash included: type of crash (overturn, ejection, collision, or other). Variables pertaining to the environment (physical or social) involved in the crash included: date, season, region, location of crash, number of users on ATV, and if another vehicle was involved.

2.3. Data analysis

Descriptive statistics were calculated using SAS version 9.3. Frequency statistics were determined for categorical variables and univariate analyses were performed on continuous variables. Chi-square tests for equal proportions were performed for the following variables: sex, diagnosis, body part injured, season, region, and location type.

A chi-square automatic interaction detector (CHAID) analysis was conducted using JMP Pro 11. This analysis tool was used to identify characteristics associated with different outcomes or variables. Like a traditional regression, a CHAID analysis sets one variable as the dependent characteristic (outcome measure) with all other variables as independent predictors. The outcome of the CHAID analysis is a classification tree that illustrates the hierarchical relationship among the outcome measure and independent predictor variables. The advantage of CHAID over regression is the ability to illustrate the clustering of variables. The method employs an iterative process, by first examining the cross tabulation between each of the predictor variables and the