

THESIS

ATV MORTALITY IN THE UNITED STATES, 2011-2013

Submitted by

Elise Lagerstrom

Department of Environmental and Radiological Health Sciences

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Master's Committee:

Advisor: David Gilkey

John Rosecrance
Sheryl Magzamen
Lorann Stallones

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ABSTRACT

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The purpose of this study is to examine contributing factors of ATV injuries and deaths through application of the Agent-Host-Environment epidemiological model. By analyzing the associations between contributing factors and classifying these factors based on the model, appropriate intervention strategies may be identified.

All US incident reports of ATV fatalities and injuries between 2011 and 2013 were obtained from the Consumer Product Safety Commission (CPSC). Each report was read and coded based on information available in the narrative incident report. Each coded variable was classified as relating to a section of the epidemiologic triangle: agent, host, or environment. Descriptive statistics were obtained for the coded variables and Chi-Square Automatic Interaction Detector (CHAID) analysis was performed in order to identify associations between predictor variables.

A total of 1,230 incident reports were obtained and, after data cleansing, a total 1,193 fatality reports remained. While only 12% of cases occurred on farms, the calculated incidence rate in the farming population (.62 per 100,000 population/year) is higher than the overall incident rate in the United States (.13 per 100,000 population/year). Descriptive statistics showed low helmet use (11.85% of fatal cases) and high use of alcohol and drugs (84.2% of fatal cases). The CHAID results showed significant associations between all types of variables: agent, host, and environment.

The present study provides nationwide statistics on ATV fatalities, approaching risk factor analysis with regard to the agent-host-environment epidemiological model. The three aspects of the epidemiologic triangle each contribute, and build upon each other, to create the combination of risk factors that lead to a fatal event.

By modeling and categorizing risk it is possible to develop targeted solutions to the root cause of the hazard. Through use of legislation and training, many host-related risk factors can be controlled, use of engineering controls can mitigate risk due to the agent and/or physical environment, and use of targeted marketing strategies and education may be able to limit risk due to the social environment.

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1. Introduction

1.1. Background

All-Terrain Vehicles (ATVs) entered into the United States market in the 1970s as an occupational tool that bridged the gap between the tractor and horse (Balthrop, Nyland, & Roberts, 2009). However, this vehicle, designed for occupational purposes, quickly developed into a recreational activity. According to the Consumer Product Safety Commission (CPSC), an ATV is an off-road, motorized vehicle having three or four low-pressure tires, a straddle seat for the operator, and handlebars for steering controls (Topping & Garland, 2014). This definition does not include motorbikes or side-by-side type off-road vehicles. ATV design has developed considerably since the 1970s due to a demand for increased safety and stability by advising bodies such as the CPSC, as well as demand for increasing speed and power by the recreational user. As technology continues to progress and enhance, ATV design has adapted in order to try to meet each group's demands. ATVs today are four wheeled vehicles, some capable of reaching speeds over 80 mph (Helmkamp, Marsh, & Aitken, 2011). Different models of ATVs have been designed for different purposes and user characteristics. There are two main categories of ATVs: sport and utility. These two different types of ATVs are used for different purposes due to design. Sport ATVs are designed to be used for recreational trail riding and racing type activities while the utility ATV is used for occupational purposes, hunting, and camping activities for its ability to be outfitted and loaded with gear and attachments (Fleming, 2010). The major differences between sport and utility ATVs are weight and suspension. Utility ATVs are heavier due to a larger engine size, a consideration made in order for it to have the capability to tow or haul heavy loads over rough terrain. Utility ATVs have less travel in the suspension than sport

ATVs, which are designed to handle jumps be more responsive in a race environment (Finley, n.d.).

The two different use profiles, recreational and occupational, differ not only in type of ATV used, but also in the user demographics and injury types. Both types of use are extremely dangerous and contribute to a large number of traumatic injuries and deaths in the United States each year. The ATVs' perception as a recreational toy masks the dangerous consequences of unsafe and untrained use. The Consumer Product Safety Commission, responsible for investigating ATV fatalities and injuries reports that more than 368,000 ATV-related injuries were treated in 2009 alone (as cited in American Academy of Orthopaedic Surgeons, 2010).

Recent studies strive to determine the common patterns of use and risk factors likely to lead to injury or death. Demographic risk factors which have been identified in previous studies include male gender (Breslau et al., 2012; Helmkamp, 2012; Rodgers, 2008; O'Connor et al., 2009; Rodgers and Adler, 2001; Helmkamp et al., 2009; Goldcamp et al., 2006; Rechnitzer et al., 2013), young or old age groups (Balthrop et al., 2009; Rodgers, 2008; O'Connor et al., 2009; Rodgers and Adler, 2001, Helmkamp et al., 2011; Helmkamp, 2012; Helmkamp and Carter, 2009), inexperience (O'Connor et al., 2009; Rodgers and Adler, 2001; Goldcamp et al., 2006), and unsafe use practices such as lack of personal protective equipment (PPE) and use of drugs or alcohol (Fleming, 2010). A position statement published by the Canadian Pediatric Society's Injury Prevention Committee on preventing ATV deaths cites that carrying passengers, poor judgment, driver decision making errors and loss of control events are the most common contributing factors of ATV injury accidents. He further cites that the most common types of ATV crashes, or mechanisms of injury, are rollovers, falling off the vehicle or ejection, and colliding with obstacles (Yanchar, 2013).

Musculoskeletal injuries and traumatic head injuries are frequent injuries resulting from the most common types of ATV crash types: overturn/rollover and collisions. According to the CPSC data from 2010, approximately 38% of emergency department treated ATV injuries are classified as a fracture, dislocation or sprain/strain (Garland, 2014). In addition, brain trauma accounts for 22% of ATV injuries (Balthrop, Nyland, & Roberts, 2009).

Environmental variables such as season, terrain, and location type have been shown to have an influence on Loss of Control (LOC) events. The design characteristics of ATVs make them ideal for off-road and occupational use. Rural ATV users encounter rough and steep terrain and are at risk due to operation far from trauma treatment centers (Rodgers, 2008); while many urban or recreational users may operate on streets, where the balloon tires of the ATV are likely to grip the asphalt and cause an overturn event. Operation in the street also poses additional risk to the user due to the opportunity for collision with other vehicles.

A variety of different prevention strategies have been implemented and proposed as solutions to offset the high rate of injury and death present during ATV use. Basic ATV design has changed from three-wheeled vehicles to four-wheeled, a change which has increased the stability of the vehicles during turning and steep terrain. Attempts have been made at different points in time by the CPSC to intervene in the noticeably rising ATV injury rate. The CPSC proposed a ten year plan, the 1988 Consent Decrees, as an agreement with the major ATV manufactures to increase safety. This program was designed to increase overall ATV safety by prohibiting the sale of three wheeled ATVs, establishing age recommendations for ATV operators, as well as establishment of training programs for new ATV purchasers (Rodgers & Adler, 2001; Myers, Cole, & Mazur, 2009). Due to the success of this ten year program and the rising injury and fatality rates after its expiration (Balthrop et al., 2009), the CPSC enacted the

mandatory 2008 Consumer Product Safety Improvement Act (CPSIA). These efforts, introduced by the CPSC, were intended to increase the inherent safety of the ATV by altering design, increasing awareness of the dangers of ATVs through training and marketing, as well as reducing the number of injuries to children by providing recommendations for reduced engine size, helmet use, and incentives for training (Catenacci, 2009; Fleming, 2010; Rodgers & Adler, 2001; Helmkamp et al., 2009).

1.2.Purpose of study

The purpose of this study is to examine contributing factors of ATV injuries and deaths through application of the Agent-Host-Environment epidemiological model. By analyzing the associations between contributing factors and classifying these factors based on the model, appropriate intervention strategies may be identified. Interventions used to break the causal chain may involve either modifying the behavior of the host, the mechanism of injury, or the environmental conditions of the event.

2. Literature Review

2.1. ATV Use

All terrain vehicles entered the market in 1971 and were praised for their ability to allow travel over terrain which was previously unreachable by means other than foot or horseback (Percy & Duffey, 1989). Since the 1970s, ATV use has developed from use as an occupational tool into a recreational toy, utilized by users of all ages. See Figure 2.1 for the different types of ATVs available for purchase. These different types of ATVs have been designed to serve different purposes and different user populations.

Figure 2.1. The different sizes and styles of ATVs available for purchase.



From Specialty Vehicle Institute of America, 2009

The US Government Accountability Office cites an industry survey in which 79 percent of ATV users claim they use their ATV for recreation while 21 percent claim they use their ATV for occupational or home chores (Fleming, 2010). The ATVs rugged appearance and speed has allowed it to become a valuable occupational tool in a variety of industries for a variety of different purposes and uses. “Officials from a manufacturer told us that utility ATVs are ideal for these types of tasks (work and chore activities) because they are able to maneuver in all types of terrain, be fitted with a number of different accessories such as snow plows and winches, and carry about six times more weight and travel more than eight times faster than a person”

(Fleming, 2010). The US Government Accountability Office (GAO) notes that ATVs are found in a variety of occupational settings including agriculture, emergency medical response, law enforcement, construction, and military applications (Fleming, 2010). See Figure 2.2 for reported use of ATVs for occupational activities.

Figure 2.2. Percentage of reported occupational activities.

Work/chore activity	Percentage of respondents reporting use
Hauling/towing	66
Landscaping/yard work/gardening	58
Property management/maintenance	44
General transportation	35
Farming/ranching	35
Snow plowing	19
Agricultural plowing or spraying	16
Construction/industrial	8
Other	6

From Fleming, 2010

While the ATV has a large number of advantages over horseback, tractors, or traditional vehicles in the occupational sector, it also results in workplace injuries and fatalities. Percy and Duffey conclude in their 1989 study of *All-Terrain Vehicle Injuries* that the presence of additional wheels, (in comparison to a two-wheeled motorcycle) contributes to a riders' confidence in the stability of the vehicle. This confidence allows inexperienced drivers the opportunity to feel comfortable moving over rough terrain at high speeds. The very reasons that ATVs are praised for their advantages also are provide some explanation of the reasons that occupational ATV use is dangerous. The addition of accessories, as well as use of the ATV for carrying heavy loads, changes the center of gravity of the vehicle, making it more prone to rollovers (OHSA, 2006). The Accident Compensation Corporation (2002) describes the mechanism: "the center of mass is shifted from the uphill wheels to the downhill wheels. When steeper slopes are traversed the center of mass ma shift... causing a loss of vehicle control" (as stated in Carman et al., 2010). ATV LOC events are not evenly distributed throughout industries

and workplace settings. “Although the April 2010 GAO report indicated an expanded use of ATVs in many occupational settings, our results have clearly shown an overwhelming majority of the fatalities have occurred in the agriculture production industry and that the number of fatalities has increased annually” (Helmkamp, Marsh, & Aitken, 2011). Carmen et al. (2010), hypothesize that the dominant LOC factor on New Zealand farms, not present in many other occupational settings, is load carrying on steep or marginal terrain present in the agricultural industry. The same study also suggests a difference exists in psychosocial attitudes of agricultural workers as compared to other industry groups. It is proposed that farmers experience these higher-than-average rates of injury due to their risk taking attitude as well as response to high fatigue and stress levels (Carmen et al, 2010). This response may lead to farmers’ higher likelihood of encountering situations and terrains leading to LOC (Carmen et al, 2010).

In addition to occupational uses, ATVs are also a common form of recreation. Recreational uses include racing, adventure riding, transportation, personal enjoyment and hunting (Helmkamp & Carter, 2009; Fleming, 2010). Recreational ATV users operate in a variety of different settings including both private and public land, which can include trails or complexes designed for ATV use, in forests, fields, or beaches, as well as operating on streets. The GAO reports that recreational riding occurs most frequently on private property. In addition, in many states across the country, areas on state or federal land have been designated specifically for use by ATVs (Fleming, 2010). See Figure 2.3 for reported use of ATVs for recreational activities.

Figure 2.3. Percentage of reported recreational activities.

Recreational activity	Percentage of respondents reporting use
Pleasure riding	84
Trail riding	66
Exploring/sightseeing	46
Hunting	40
Camping	25
Fishing	21
Hiking/backpacking	8
Competition/racing	6
Other	7

From Fleming, 2010

Both recreational and occupational users operate their ATVs in a variety of conditions and terrains. According to the CPSC’s definition of an ATV, as well as the fundamental design concepts, these vehicles are intended for exclusively off-road use. Problems occur when the ATV is used outside of its designed purpose. For instance, while some ATVs have the ability to reach speeds acceptable for highway use, their use of low pressure tires is hazardous for use on paved surfaces. This design feature and use characteristic contributes to the statistic that two-thirds of ATV crashes occur on roads (Insurance Institute for Highway Safety, 2013). Ford and Mazis explain: “The balloon tires that provide good traction on non-paved terrain can contribute to rollovers on paved surfaces. The tires grip macadam or concrete and tend to pull the vehicle over during turns” (1996).

Recreational and occupational users have different use profiles and different operating characteristics. In addition to purpose of use, factors pertaining to site of use play an important part in the user profile. There are different use characteristics between urban and rural riders. Rural riders may ride on less developed terrain over longer distances and for longer periods of time, rely on ATVs frequently for transportation, and, are also less likely to have access to emergency medical treatment when accidents do occur (Rodgers,2008). Being further from emergency medical services and definitive care can result in increased morbidity and mortality

as well as difficulty accessing ongoing care for recovery of injuries. The presence and enforcement of state and local laws and regulations also influences the demographics and use patterns of ATV operators.

2.2. History

After realizing the increasing injury rate that came with the developing ATV industry, increasing rate of sales, and assembling reports on the demographics and common injury patterns, in 1988 the Consumer Product Safety Commission released a set of decrees to increase ATV rider safety. The five major ATV manufactures at the time participated in the voluntary decrees for a pre-determined ten year time period. “Under the decrees, the industry agreed to cease production and sale of new 3-wheeled ATVs, implement a rider-safety training program nationally, and to develop a voluntary standard to make ATVs safer. Warnings and age recommendations were included on the vehicle and in advertising” (Pediatrics, 2000). These decrees were aimed at preventing deaths by focusing on the inherent design dangers of the 3-wheeled ATV, the rising injury rate in children, and education of the growing population of new ATV owners. The decrees were largely successful in this effort. “By 1997, the rate of injures treated in emergency departments had fallen to about 1,490 injures per 100,000 ATVs in use, a decline of over 70 percent from the 1985 level” (Rodgers & Adler, 2001). However, upon expiration of the decrees in 1998, the injury rates once again began to climb. “According to the CPSC, estimated emergency room-treated ATV injuries increased by 101% from 1998 to 2004. Several US trauma centers have corroborated these findings, showing an increase in ATV-related injures since the expiration of the decree” (Catenacci, 2009).

Due to rising injury rates after the expiration of the decrees the CPSC re-introduced similar decrees. The Consumer Product Safety Improvement Act (CPSIA) was introduced in

2008 and gave the CPSC authority to make the standards mandatory throughout the United States ATV industry as well as other industries under the purview of the CPSC. Industries included are identified as posing a significant safety issue to the consumer use. The act, while introduced in 2008, did not become effective until April 2009. This standard, focused on the same goals as the original decrees, required development of ATV action plans by manufactures to decrease rising injury rates, and prohibited the distribution of three-wheeled ATVs (Topping & Garland, 2014).

Part of the CPSIA includes a requirement for an action plan to be developed for every ATV manufacturer. These action plans must be filed and approved by the CPSC before the manufacturer is able to sell their product in the United States (Fleming, 2010). Components of an ATV action plan include: “Three-wheeled ATVs no longer manufactured, prohibition of the sale of adult-sized ATVs to or for children younger than 16 years, promotion of ATV safety thinking, and promotion of safety education campaigns” (Phrampus, Shultz & Saladino, 2005).

In addition to federal regulations, each state has developed specific laws pertaining to the sale and use of ATVs. These laws pertain to a variety of issues surrounding ATV use including: road use and highway crossing, speed limits, public land use, safety equipment use, age requirements, passengers, and licensing requirements (Hansen & Shinkle, 2013). Many states have regulations in place for the use of ATVs. Examples of regulations include prohibition of use on public roadways, limits on vehicle size, and helmet use. Aitken et al. (2004), cite that 21 states have a requirement in place requiring helmets or safety equipment use by ATV users. A chart summarizing the ATV laws by state, compiled by the Specialty Vehicle Institute of American (SVIA) in 2009, can be found in Appendix I.

Training for ATV operators began initially with the 1988 decrees where the CPSC identified a need for specific training for ATV users. The US Government Accountability Office states that: “Training is important because operating an ATV seems “deceptively easy.”... The operator requires situational awareness to negotiate unpaved terrain with both eye-level hazards... and trail level-hazards... and quick judgments relating to steering, speed, and braking as well as relating to terrain suitability, weight shifting and other active riding behaviors” (Fleming, 2010). In 1988, the All-Terrain Vehicle Safety Institute (ASI) was formed as a part of the SVIA. ASI was formed to provide safety education as a part of the 1988 decrees. According to atvsafety.org, the ATV Safety Institute was formed in order to promote safe use of ATVs in order to reduce the number of accidents and injuries that occur due to unsafe and inexperienced operation.

Training programs continue to be a part of the CPSC’s safety initiative. As a part of the mandatory 2009 CPSIA, dealers and manufacturers must provide incentive to new ATV purchasers for participating in an approved safety course. This approved training course must be provided free of charge to all first-time ATV purchasers and their family members. Dealers and manufactures must also offer a minimum of a \$100 incentive for participating in the training (Fleming, 2010). In order to ensure that the trainings conform to the CPSCs mission, training programs must be approved by the commission in order for users to be eligible for the incentive program. Problems arise with the availability of training programs, which may be one reason why so many new riders are opting out of participating in a training program. “As of February 2010, Commission staff indicated that only the training provided by the Specialty Vehicle Institute of America’s ATV Safety Institute met the requirement. The Safety Institute’s course, which takes about 4 to 5 ½ hours, encompasses safe riding practices, such as how to operate

ATVs on hills and on various types of terrain; the importance of wearing protective gear; and the hazards of improperly operating the vehicles” (Fleming, 2010).

Reasons for not participating in the training program go beyond availability. While many users did not have access to adequate training, others simply did not know of the existence of the approved training programs and subsequent incentive programs, or simply did not want to participate in the training programs. According to a study by Brugus, Madsen, Sanderson and Rautianien only 22% of ATV users surveyed participated in an ATV safety training course. Many respondents claimed they were not interested in taking the training, while 24% responded that they did not need training and 16% claimed that they were already safe operators (2009).

According to the ASI, their RiderCourseSM is a half-day training program that encompasses the following skills: pre-ride inspection, starting and stopping, quick turns, hill riding, emergency stopping and swerving, and riding over obstacles. Participation in the course is free and available to all ages, although, parents must be present for riders under the age of 12 (ASI, 2014). A safety information sheet published by ASI reports that they have trained over 945,000 riders, have more than 2,500 licensed instructors, who are responsible for conducting 150-200 training classes each week.

In addition to the hands on training course, ASI also provides resources for parents and educators to help inform youth of the responsibilities and risks of riding ATVs for both recreational as well as occupational purposes. There are multiple public service announcements as well as brochures on the availability of training programs, how to become a trainer, quick training tips as well as information on personal protective equipment. See Figure 2.4 for a marketing advertisement created by ASI promoting proper PPE.

Figure 2.4. ATV Safety Marketing Advertisement.



From ATV Safety Institute, n.d.

<http://www.atvsafety.org/ASIPSA.aspx>

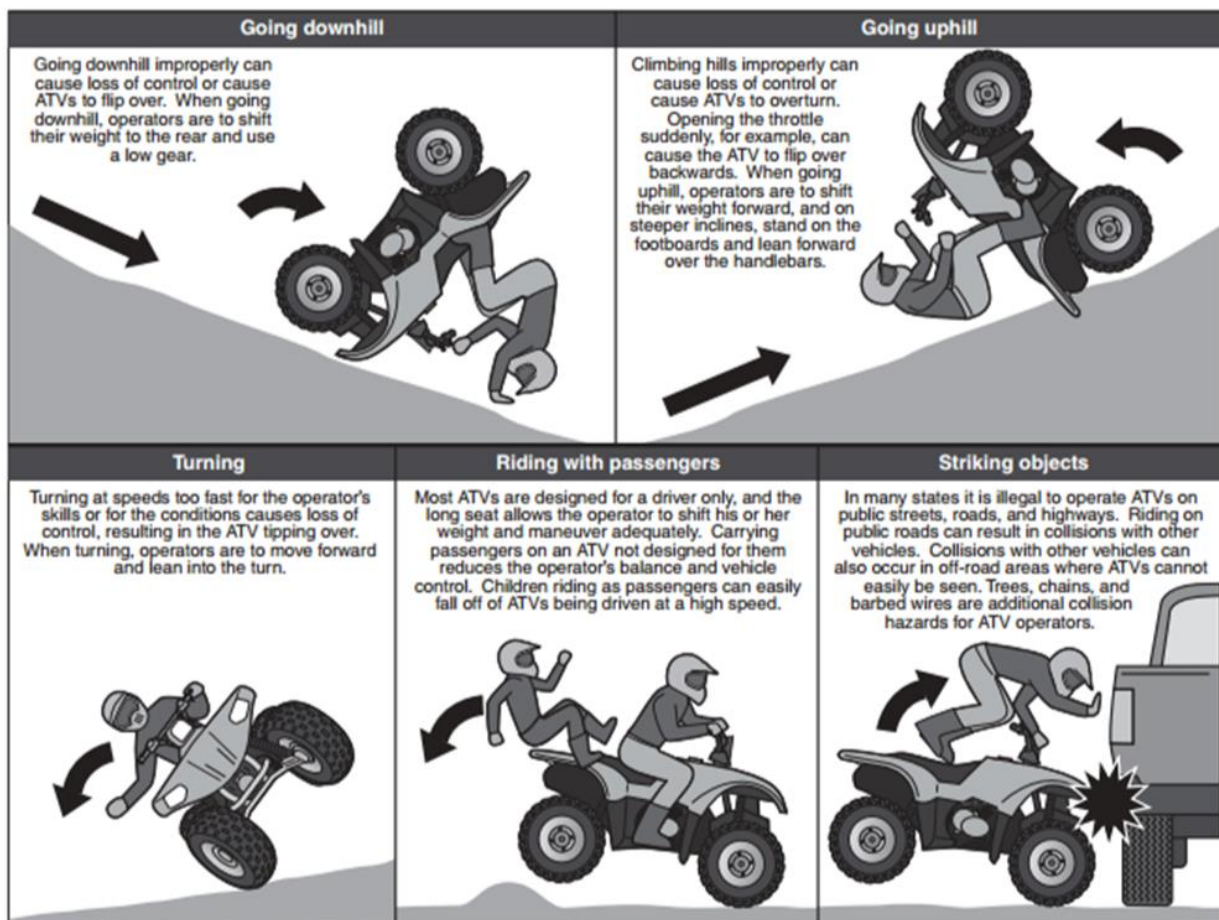
2.3.ATV injury and deaths

The CPSC began conducting interviews and investigations into ATV LOC events, injuries, and deaths in the 1980's (Helmkamp, Marsh, & Aitken, 2011) in order to better understand the rising injury rate associated with these new vehicles. One of the problems encountered during investigations is not understating or having witnesses to the circumstances surrounding the crash. ATV riders often ride alone, and in the case of serious injury or death, many facts surrounding the circumstances of the incident are lost. This presents a problem for understanding the causal factors and social circumstances surrounding the most serious ATV accidents. "Fatal accident often occur without witnesses and, since the victims cannot be interviewed, it is often difficult to gain a clear understanding of their riding patterns and how the accidents occurred" (Rodgers, 2008). Even the most basic details, such as lighting conditions, weather conditions, and time of day may be almost impossible to obtain when accidents occur without witness.

The injury reports and interviews by the CPSC allow for determining the most common use patterns and injury types associated with ATV use. Williams, Oesch, McCartt, Teoh, and Simms research concludes that the majority of ATV crashes occur in rural areas as a result of a single ATV collision with a fixed object or a rollover as a result of excessive speed (2013).

ATV loss of control (LOC) events are fairly common and occur for a variety of different reasons. Between the years of 1982 and 2012 the CPSC received reports of 12,391 ATV related fatalities (CPSC, 2014). These reasons are dependent on the operator, environmental and social conditions, as well as design of the ATV. See Figure 2.5 for an illustration of the most common types of LOC events. The investigative work done by the CPSC has allowed changes in

Figure 2.5. ATV Loss Of Control Events.



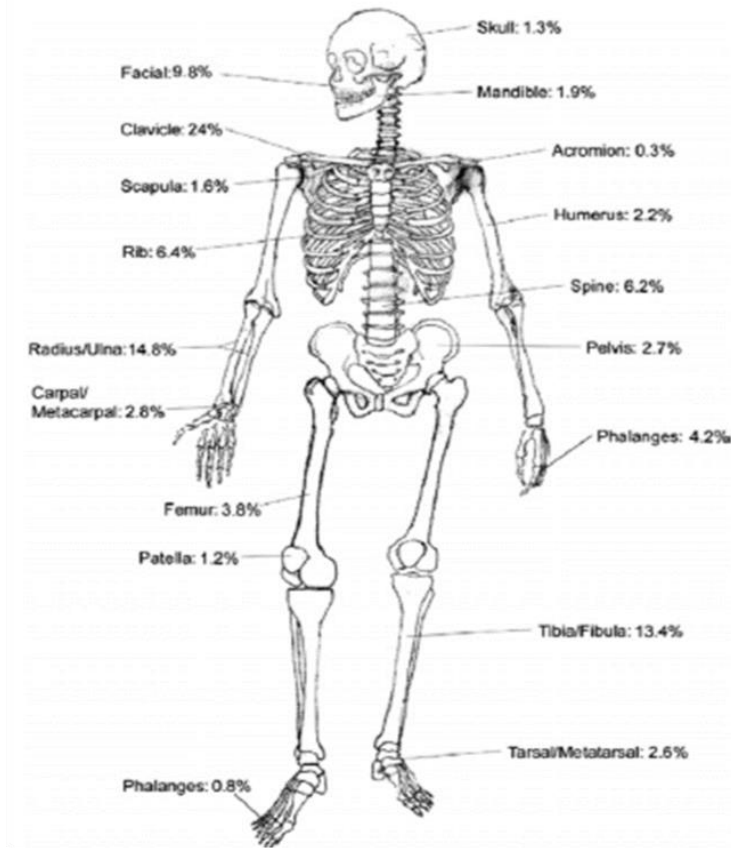
From Fleming, 2010

legislation, design, and education to be made in order to reach people at high risk for having ATV accidents.

There are many different types of traumatic injuries that may be sustained during an ATV accident which are dependent on rider characteristics and the circumstances of the accident. These injuries are contingent on the crash type, speed, basic demographics, presence of drugs and alcohol, and co-morbid conditions. As mentioned before, the inherent characteristics of an ATV make it prone to rollover while offering no protection from this type of event. “The rider of an ATV is unrestrained and poorly protected; hence, injuries requiring medical care are typically secondary to head, face, and orthopedic trauma. Ophthalmic trauma ranges from minor superficial injuries to complex orbital fractures and vision loss. Extremity fractures are common, and in general, orthopedic injuries are the most common injuries associated with ATV accidents” (Phrampus, Shultz & Saladino, 2005). While injury statistics vary greatly in accordance with the factors mentioned previously, “64.8% of all ATV accident related injuries involve either the arm, shoulder, leg or foot” “45% could be classified as musculoskeletal, with fractures or dislocations accounting for over 30% of all injuries” Trauma to the head or brain accounted for 22% of all ATV accident-related injuries” “The most common fracture sites were the clavicle (24%), forearm (14.8%), and tibia/fibula (13.4%)” (Balthrop, Nyland, & Roberts, 2007). See Figure 2.6 for an image of the most common injury and fracture sites.

These injuries are often associated with emergency treatment and associated hospital stays. ATV related hospitalization patients tend to be younger and involve a shorter stay than the average injury hospitalization. However, the costs associated with a hospitalization from an ATV accident and subsequent injury is approximately 30 percent higher than other hospitalizations for injuries or accidents (Breslau, Stranges, Gladden, & Wong, 2012).

Figure 2.6. Most Common Sites of ATV injures with Prevalence Statistics



From Balthrop, Nyland, & Roberts, 2007

2.4.Host Risk Factors

There are many different risk factors that may contribute to the likelihood and severity of loss of control. Data analyzed by Helmkamp, Marsh, and Aitken from the BLS Census of Fatal Occupational Injuries (CFOI) they found that contributing factors for recreational ATV crashes include excessive speeds, not wearing a helmet, lack of training, and the presence of passengers (2011).

Demographics of injured users differ between recreational and occupational users. Recreational riders/passengers tend to be male, have a lower average age than occupational users, and are more likely to be intoxicated with alcohol (O'Connor, Hanks, & Steinhardt, 2009).

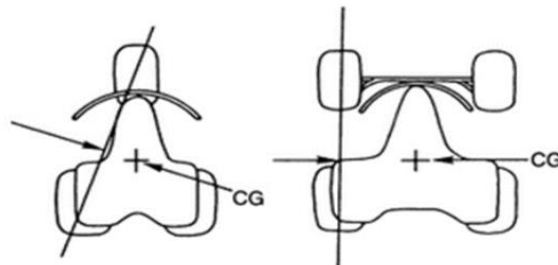
Gender also plays into the risk of injury and death. While it is true that a majority of ATV riders are male, males are also more likely to die or be injured in a crash. CPSC data from 2001 estimates that there were 13.5 million male ATV riders in the United States in comparison to only 9.4 million female riders (Levenson, 2003). In addition, male riders logged approximately 1,846 million riding hours in comparison to females 761 million hours (Levenson, 2003). These measures were used to calculate the injury rate per million riding hours for both male and female riders. Levenson (2003), found that males have an injury rate of 46.7 injuries per million riding hours, while females have an injury rate of 30.0 injuries per million riding hours. Helmkamp, Aitken, and Lawrence explain gender differences in both ATV incidents, as well as cycling incidents, as a combination of both exposure and behavior. They conclude that males are more likely to engage in risky behaviors, which contributes to the higher injury rates in the male gender (2009). In a study of the effectiveness of ATV Safety education, results indicated that males were more likely to ride outside the designed use of ATVs (on paved surfaces), more likely to ride larger and more powerful ATVs, have higher overall injury rates than females, and be less likely to attend safety courses (Burgus, Madsen, Sanderson & Rautiainen, 2009).

Psychological factors also play into the likelihood of injury. A study conducted by Mangus, Simmons, Jacobson, Streib, and Gomez examines the changes that are made by an ATV or motorcycle user after experiencing a crash. Findings suggest that the users who were taking risks in the past (engaging in unsafe behavior and not wearing proper personal protective equipment) were still less likely to wear a helmet in the future than riders who had not been in a previous event. This shows a pattern of injury recidivism and patterns of risky behavior that do not change with an injury or near miss event. "Injury recidivism among trauma patients is well documented and may result from an accumulation of risk factors... these people are less likely to

adopt proactive behaviors such as use of... helmets,... obeying traffic laws, and avoidance of volatile psychosocial situations” (Mangus, Simmons, Jacobson, Streib, & Gomez, 2004).

Rider height and weight characteristics play a role in the stability of the ATV. Research by the CPSC hypothesizes that the weight of the operator as well as the slope of the terrain both play a statistically significant role in injuries during overturn events. The CPSC concludes that as slope and driver weight increases so does the likelihood of an overturn event (May 2014). The same principle of applies to occupational riders who alter the weight and balance of the vehicle by adding after-market additions such as sprayers and plows to the vehicle. These additions may make the vehicle more likely to overturn on a slope due to further raising the center of gravity of the vehicle. Users with a greater weight have a higher likelihood of tipping the vehicle outside of its righting moment, especially if that increase in weight comes with an increase in height of the rider, which subsequently raises the center of gravity of the unit. “For the weight category <100 lbs., only 36.8 percent of the estimated injures were related to an overturning event; while the 150-199lbs and the 200+ categories 66.1 percent and 65.5 percent, respectively of the estimated injuries were related to overturning events” (Garland, 2014). See Figure 2.7 for an image of the center of gravity and righting moment of a three- and four-wheeled ATV.

Figure 2.7. Righting Moment and Center of Gravity of Three- and Four-Wheeled ATVs



From Percy & Duffey, 1989

Age is an important risk factor for ATV injuries and fatalities. The higher risk of LOC events and subsequent injury has been highly studied by a variety of researchers, leading to

legislation changes in many states and finding its place in the 2008 CPSIA. Research conclusions on children's ATV injuries and deaths are fairly consistent across different databases and research techniques. The 2012 CPSC report stated that: "From 1982 through 2012, CPSC staff received reports of 2,944 ATV-related fatalities of children younger than 16 years of age. This represents 24 percent of the total number of reported ATV-related fatalities...1,267 (of 2,944) were younger than 12 years of age" (CPSC, 2014). Aitken et al. cite a similar statistic in their 2004 report "All-Terrain Vehicle Injury in Children: Strategies for Prevention." "Although children under 16 make up only 14% of riders, they comprise 35% of all deaths caused by ATVs and demonstrate a risk of death 4.5-12 times greater than adult comparison groups." In a study of Emergency Department records using the Healthcare Cost and Utilization Project, Nationwide Inpatient Sample, and the Nationwide Emergency Department Sample, Breslau, Strange, Gladden, and Wong studied the characteristics of ATV-Related injuries treated in emergency departments across the country in 2009. With respect to age, they found that "Risk for ATV injury related ED visits peak in early adolescence, reaching a rate of 10.2 per 100,000 population among people ages 13-15" (2012). This is a troubling statistic due to the fact that in that the 2008 CPSIA recommended the prohibition of sale of adult-sized ATVs to children under the age of 16. This recommendation was made due to research findings that "Nearly 90% of ATV-related injuries suffered by children under age 16 were caused by adult-sized ATVs... Youths account for more than 33 percent of the ATV fatalities, but made up only 14 percent of the riders" (Murphy & Harshman, 2005). The American Academy of Pediatrics advocates that children under the age of 16, or operators without a license to drive a motor vehicle, should not be allowed to operate an ATV due to lack of the needed motor skills, strength, and judgment needed for safe operation (2000). Murphy and Harshman from the College of Agricultural

Sciences Cooperative Extension at Penn State suggest evaluating the child's physical and emotional development when determining a child's readiness to operate an ATV. They also make the following suggestions when selecting the correct ATV for a youth: purchase of a four wheeled vehicle, selection of ATV engine size based on age of operator, selecting a automatic transmission, and supervisory controls such as throttle limiters or remote shut-off (2005).

While the risk to children and teens with respect to ATV incidents has been identified and studied extensively for a period of time, recently, the elderly population is becoming of increased interest as well. The CPSC released a document in 2014 that identified a statistically significant positive trend in the injury rate of ATV operators aged 55+ in the years 2001-2012. This corresponds to a rising rate of injury among the oldest operators (CPSC, 2014). Possible reasons for the increased mortality are explained by Helemkamp and Carter:

The earlier study of ATV deaths among older adults in West Virginia suggested that multiple physical and sensory limitations potentially experienced by older adults may exacerbated the inherent dangers associated with ATVs and produce different crash dynamics that in incidents involving younger ATV operators. These limitations may include decreased reaction time, visual and hearing limitation, polypharmacy, decreased circulation, decreased strength and muscle range of motion that affects mobility, balance, reaction time, and endurance. Moreover, these changes may not only place older adults at greater risk of experiencing an injury, but may affect the seriousness of the trauma event. For example, certain medications, such as anticoagulant, may complicate trauma care" (2009).

Not only are older adults getting into more incidents, these incidents are also more likely to be injured or killed than users of a younger generation. "Older riders >50 suffered more frequent and severe thoracic injuries, were less likely than younger riders to be discharged to home, and had more complications" (Catenacci, 2009). "The fatality rate observed for the oldest group (1.14) was over 10 times higher than the collective rate among the three youngest groups (0.11). Furthermore, a subset of this oldest group included those engaged in agriculture

production work who died at a rate of 13.4, a rate over twice that of the overall industry” (Helmkamp, Marsh, Aitken, 2011).

In a survey of Arkansas youth, Jones and Bleeker wanted to determine the differences between injuries and use patterns of farm versus non-farm youth. Jones and Bleeker found that youth who use ATV in a farming or agricultural setting have higher usage rates and are also more likely to operate the ATV with only a single rider (2005). Risk factors identified in this report were operating an ATV with passengers in addition to the driver, as well as number of times the ATV was in operation per week. In summary, farm youth have a higher risk of injury due to their higher use of ATVs, but a lower risk due to their ATV use as a single rider.

Operating an ATV while carrying a passenger has been recognized as a high accident and injury risk situation... (the CPSC) recommend(s) that ATV operators never allow passengers. Consumer ignorance of or non-compliance with this recommendation leads to this common behavior, particularly among the pediatric population (Balthrop, Nyland, & Roberts, 2007).

Carrying passengers increases risk due to the effect of the passengers weight and balance has on the drivers' ability to effectively steer and control the ATV. “The driver often needs to make quick body weight shifts combined with acceleration and braking. A passenger can impair the safe operation and maneuverability of the ATV and the additional passenger weight may exceed the manufacture's weight limit” (OSHA, 2006). As discussed earlier, additional weight, even in the form of passengers, changes the center of gravity of the vehicle and may cause vehicle instability.

Another risk factor, especially common among recreational users, is alcohol and drug use. In a study conducted by Percy and Duffey, patients who were admitted to University Medical Center Emergency Department were interviewed on details surrounding their ATV injuries. This study identified several risk factors and demographic characteristics including

information on alcohol use. According to this study, approximately 30% of surveyed participants admitted to alcohol use before or during ATV operation (Percy & Duffey, 1989). A study out of Nova Scotia revealed similar statistics with regard to alcohol consumption statistics. This study found that alcohol use was involved in 24-56% of cases and that alcohol use was associated with injury severity and hospital stay length (Sibley & Tallon, 2002).

Experience level and training are two factors with mixed results throughout the literature in terms of effectiveness in reducing injuries and LOC events. CPSC data indicate that “during the first month of operation, new recreational ATV drivers have an injury rate 13 time higher than the overall average injury rate for ATV operators” (OSHA, 2006). In a case-control study by Rodgers and Adler they found that risk of injury declined with driving experience. In this study, experience was measured in years of ATV use. Using a logistic regression “it can be shown that a 1 percent increase in driving experience (measured in driving time) results in an estimated risk reduction of about 0.4 percent” (2001). Also included in the study was an evaluation of risk with respect to driving time per month. They found that estimated risk rises with amount of use, but risk is also high for users who are inexperienced and use ATVs infrequently. Rogers and Adler explained the reason for the higher risk to less experienced drivers by citing that ATV use requires a high level of skill to negotiate the changing terrain and environmental characteristics (2001). Data from the CPSC also suggests that lack of experience and training may contribute to LOC and injuries. The CPSC report concluded that the more that the ATV is used, the greater likelihood of an injury, however, the risk of injury per ride decreases with experience (Goldcamp, Myers, Hendricks, & Layne, 2001).

2.5. Agent Risk Factors

According to CPSC data, 50% of ATV accidents are due to rollover (as cited in Balthrop, Nyland, & Roberts, 2007). The mismatch between the design characteristics of an ATV and the dynamics of a LOC event that results in injury in a high proportion of cases. “ATV safety philosophy retains and promotes, quite inappropriately, a motorcycle based and rider-centered perspective on safety, rather than a vehicle one. That is, ATV safety is considered to depend on rider separation from the vehicle and the addition of protective clothing and helmet... They do not offer any protection in the most common modes of injury with ATVs—rollovers, nor collisions.” (Rechnitzer, Grzebieta, McIntosh, & Simmons, 2013).

While ATVs are capable of speeds up to 70 mph (Brown, Koeplinger, Mehlman, Gittelman & Garcia, 2002; Murphy & Harshman, 2012), LOC events are less likely to occur at high speeds (Balthrop, Nyland & Roberts, 2009). A study of emergency department treated LOC events estimated the speed of 35% of LOC events to be less than 10 mph and only 25% to be at speeds 20 mph and above (Garland, 2014).

Operating a vehicle too large or powerful for the operator’s size or ability may decrease the users’ ability to actively steer and maneuver the vehicle. Recommended limits on engine size for youth operators have been made in order to prevent injuries due to the operators’ inability to handle a large engine. The ATV Safety Institute recommended that users under the age of 16 operate vehicles with a maximum engine size of 90cc (Burgus, Madsen, Sanderson & Rautiainen, 2009). In a survey of youth ATV operators, nearly all respondents less than 16 years old reported riding an ATV with an engine size greater than 90cc (Burgus, Madsen, Sanderson & Rautiainen, 2009). A separate study found that nearly 90% of youth under 16 who had been

injured in an ATV LOC event were riding an ATV with an engine size greater than 90cc (Murphy & Harshman, 2012).

2.6.Environment Risk Factors

While many changes have been made to ATV design and safety features, such as eliminating 3-wheeled ATVs from the market, the basic design of the ATV gives it handling characteristics ideal for off-road environments, yet unstable on-road conditions. ATVs taken outside of their intended off-road use may result in instability and increased likelihood of a LOC event. Instability is created by through the use of low pressure and knobby tires. This type of tire while ideal for off-road use, is not recommended for paved surfaces (American Academy of Pediatrics, 2000). Use of an ATV on paved surface is especially dangerous when carrying passengers or cargo or while operating at excessive speed (Helmkamp, Marsh, Aitken, 2011).

In addition to the dangers of operating on paved roads, previous studies have identified farms and agriculture operations as locations with higher rates of ATV injuries, with livestock operations having a higher rate of injury than crop operations (Goldcamp, Myers, Hendricks, & Layne, 2001).

The environmental conditions of LOC events differ between ED treated injuries and fatalities. Emergency department treated injuries are more likely to occur in a field (20%) or woods (20%) while fatalities are more likely to occur on paved (34%) or unpaved (20%) roads (Garland, 2014).

One of the problems regarding medical care for rural ATV injuries is the lack of availability of Emergency Medical Services (EMS) in many areas where ATV use is common. “The rural setting of these accidents has multiple potential implications in initial patient treatment and long-term outcome after treatment cessation” (Balthrop, Nyland, & Roberts,

2007). Even if injured riders are able to survive a crash, after release from the hospital, the rural residence of many riders may make it difficult to access continuing care for injuries, such as physical therapy and rehabilitation services. The rural rider may also be more likely to encounter harsh terrains and operate under less ideal conditions than the recreational, urban rider (Rodgers, 2008).

2.7.Prevention Strategies

Many different strategies have been used to combat the high rates of ATV injury and fatality rates across all demographics. Proper training, use of personal protective equipment, additional regulations and legislation, as well as marketing campaigns are strategies that have been implemented and tested against the rising injury rates.

Training involving a hands-on segment is designed to counter several risk factors of ATV use. First, it is used to provide users with an opportunity to practice skills in order to become experienced users. By training users to operate vehicles correctly over a variety of different terrains, training may help reduce risk of LOC events in new users.

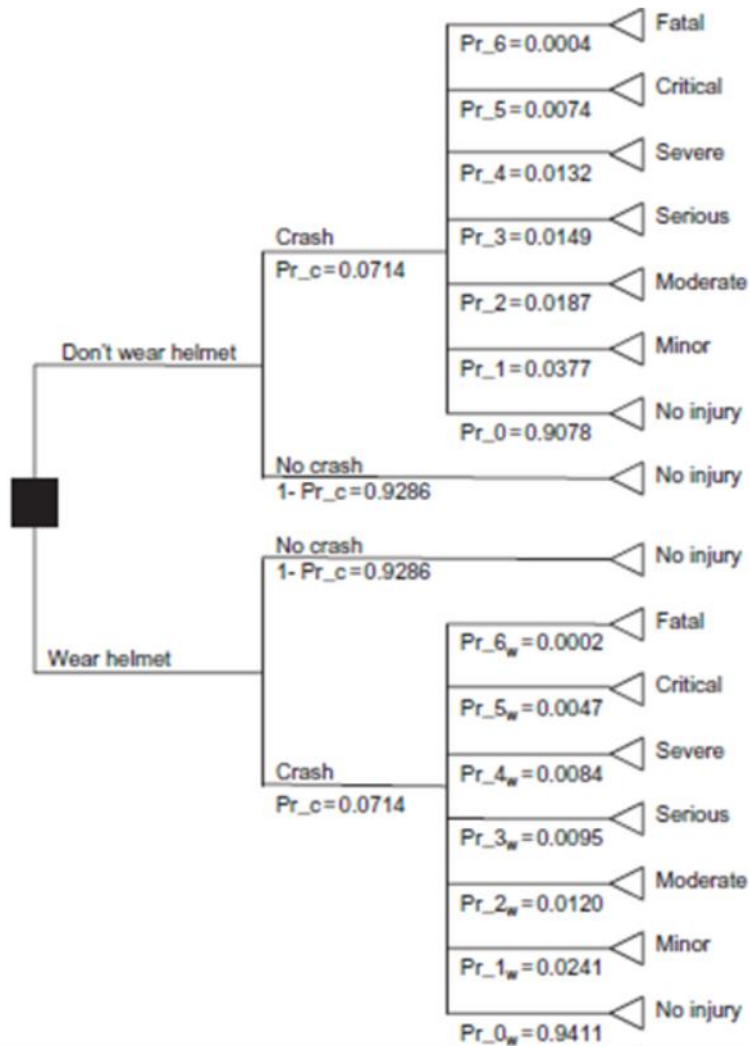
Many occupational users, unlike recreational users, are mandated to enroll in approved safety training (Helmkamp, Marsh, & Aitken, 2011). Helmkamp, Aitken, Graham, and Campbell found that “Training requirements were not associated with a marked difference in death rates, although some high-risk subsets did show lower rates in states with training requirements.” However, some of this decrease may be attributed to the increase in ride time and understanding of riding principles that would have developed whether or not in a training environment (2012). They conclude that current training data is incomplete in determining the effect it has on changing behavior and that more research needs to be conducted in order to determine how much and what type of training would be most effective in reducing ATV injuries.

In addition to the driving skills that can be communicated and practiced in an ATV safety course, information can be provided on the necessity and proper use of personal protective equipment.

Personal protective equipment (PPE) is an important element of reducing the severity of injuries in the event of a LOC event. Helmets, protective clothing, boots, and goggles are all part of the recommended PPE of ATV users both occupationally as well as recreationally. Percy and Duffey (1989), in a review of emergency department data and subsequent interviews of injured users, found that “most of the accidents and injuries presented in this study could have been avoided or prevented (with proper use of PPE)” (Percy & Duffey, 1989).

Findings from several studies suggest that a helmet is an extremely valuable component of the PPE due to the high likelihood of head and neck injuries in the event of overturn and collision type events. “The helmet is the single most important protective device for avoidance of severe injury for riders of ATVs and motorcycles, and is the most widely publicized and legislated” (Mangus, Simmons, Jacobson, Streib, & Gomez, 2004). Myers, Cole, and Mazur report that one-fifth of ATV hospitalizations are a result of head injuries which is a greater proportion than motorcycle injuries (2009). Furthermore, the same study reports that helmet use results in a 42% reduction in risk of death and 66% reduction in risk of non-fatal injury in the event of LOC. “Taking into account the social direct and indirect costs of fatal and nonfatal head injuries at a 5% discount rate, US\$364,306 could be saved per injury averted over a 50-year period if there were universal wearing of head protection by ATV drivers” (Myers, Cole, & Mazur, 2009). See Figure 2.8 for a decision tree matrix corresponding to probabilities of injury severity between helmet users and non-helmet users.

Figure 2.8. Probabilities of Injury Severity based on Helmet Use



From Myers, Cole, & Mazur, 2009

While there have been mixed results in the effectiveness of regulations as it pertains to ATVs, helmet regulations have proven to be somewhat effective in reducing the severity of injuries to ATV riders who experience an ATV accident. “Nearly 5,300 deaths occurred in the states with helmet-use requirements, at a rate of 0.30 per 100,000 population, compared with more than 1,900 deaths in the states with no helmet-use requirements, which had a rate that was 23% higher (0.37 per 100,000 population)” (Helmkamp, Aitken, Graham, & Campbell, 2012).

The lower risk of death in states with helmet requirements suggests that legislation may be effective in reducing death and injury rates.

The effectiveness of helmets has been demonstrated through many studies and reports. However, the difficulty is convincing users the necessity of helmet use in occupational as well as recreational settings. Results were obtained in a study performed relating to helmet use in ATV users who had been involved in a previous accident. “Persons with a history of both minor and major ATV/motorcycle related injury were less likely to report current use of either helmets or protective equipment compared to persons without a previous injury.” The authors go on to further explain their findings with “These findings certainly suggest a pattern of persistent high risk behavior among previously injured persons, even when these injuries are severe” (Mangus, Simmons, Jacobson, Streib, & Gomez, 2004).

Other PPE worn by the rider that can be used to prevent injuries include protective clothing, boots, gloves, and goggles or face shields. By covering extremities with protective clothing, abrasions and lacerations can be prevented (Percy & Duffey, 1989).

In addition to protective equipment that is worn by the operator, there are opportunities for improved safety by modifying the design and components of the ATV. Proposed ideas include: instillation of flags, reflectors and lights, seatbelts and roll bar installation, headlights that automatically turn on, speed governors, engine covers, and a leg guard (American Academy of Pediatrics, 2000).

In order to combat risk factors and unsafe riding practices, several organizations have recommended the implementation of laws and regulations as it pertains to ATV use.

The American Academy of Orthopaedic Surgeons (AAOS) provides the following recommendations for regulations that should be applied in order to reduce the ATV injury rate:

1. Require a license based on “demonstrated competence” (eg. Completion of a skill-based test),
2. No operation by users under the age of 12,
3. Limits on riders ages 12-16. (eg. smaller engine size, and supervision),
4. Require safety equipment such as helmets, safety goggles, boots, and long sleeves,
5. Operate exclusively during daylight hours,
6. Single person use,
7. No operation by users under drugs or alcohol (AAOS, 2010).

The American Academy of Pediatrics (AAP) makes similar recommendations to increase rider safety, especially for the young rider population. The AAP recommends:

1. Continue educating parents and children on the hazard of ATVs,
2. Children not licensed to drive a car should not operate ATV (eg. No users under the age of 16),
3. Double riding is not permitted,
4. Require protective equipment and reflective clothing,
5. Prohibit street or night use,
6. Use of lights and reflectors to make the ATV more noticeable,
7. Prohibit use of alcohol for ATV users, and parents should set a positive example for their children on abstaining from alcohol while operating a motorized vehicle (AAP, 2000).

While these organizations support the creation of rules and regulations, reasons for not enacting these regulations in states is twofold: there is concern about the level of support for the new regulations as well as logistical problems on enforcement of the regulations if they are passed. “In theory, appropriate legislative intervention should have a dramatic impact on safety because it provides a standard for an entire population; however, previous literature examining the effectiveness of ATV regulations suggests that this is not the case ... These prior studies point out what we deem to be the inherent flaws in a legislation-dominated approach to injury prevention—compliance...enforcement... and an infinite number of independent variables” (Winfield et al., 2010). “Absence of laws, weakness in those that exist, and enforcement challenges hamper law-based approaches to protecting ATV rider” (Williams, Oesch, McCartt, Teoh, & Sims, 2013). Stolz, McKenzie, Mehan, and Smith call for establishing the opinion of

voters prior to enacting legislation in order to determine the most effective means of injury and fatality prevention (2009).

Regulations have mixed results when it comes to success in compliance and reducing the injury rate and injury severity. In other recreational areas such as cycling and motorcycle use, laws have been effective in increasing helmet use and decreasing morbidity as well as mortality. If the same success is seen in the area of ATV use, enacting legislation to require helmets for children and youth could help reduce rising injury and fatality rates (Stolz, McKenzie, Mehan, & Smith, 2009). “It is inherently dangerous to ride an ATV regardless of measures taken to prevent injuries. To curb the number of debilitating injuries and unnecessary loss of life, new legislative policies have to be enacted and rigorously enforced to ensure that all riders regardless of age, can demonstrate competency and responsibility in handling these powerful recreational vehicles” (Thepyasuwan, Wan, & Davis, 2009).

In addition to education through training programs, there are also marketing campaigns aimed at reducing injury rates by increasing awareness of proper PPE as well as the inherent dangers of operating an ATV. See Figure 2.9 for an example of a marketing campaign launched by the AAOS and Orthopaedic Trauma Association (OTA). The CPSC has launched a campaign to increase ATV awareness and the availability of safety training. Through marketing such as television and radio public service announcements the CPSC hopes to reduce the number of deaths and injuries associated with ATV use. In addition to the marketing campaign, the CPSC launched a website, www.ATVSafety.gov, with information in regards to fatality data, safety information, and laws and regulations associated with ATV operation (CPSC, 2014). “Similar to tractor safety programs, to reach this population, information about safe operation and the

inherent dangers of ATVs may be best conveyed through venues such as farm bureaus, farm magazines, and equipment dealers” (Helmkamp, Marsh, Aitken, 2011).

Figure 2.9. AAOS and OTA Marketing Campaign

Over the river and through the woods to the trauma center we go.



All-terrain vehicles can go 60 mph and weigh 600 pounds. Yet, many owners think of them as just big toys. Consider the facts: 136,000 ATV-related injuries were treated in hospitals and doctors' offices in 2004. Accidents happen when ATVs are operated in the wrong place, under the wrong conditions, by people too young or too inexperienced in ATV safety measures. If you must ride an ATV, use your head — the right way. A public service message from the American Academy of Orthopaedic Surgeons and the Orthopaedic Trauma Association.

For recommendations on ATV safety, visit orthoinfo.org and ota.org.

AAOS
AMERICAN ACADEMY OF
ORTHOPAEDIC SURGEONS

OTA
ORTHOPAEDIC TRAUMA ASSOCIATION

From Fleming, 2010

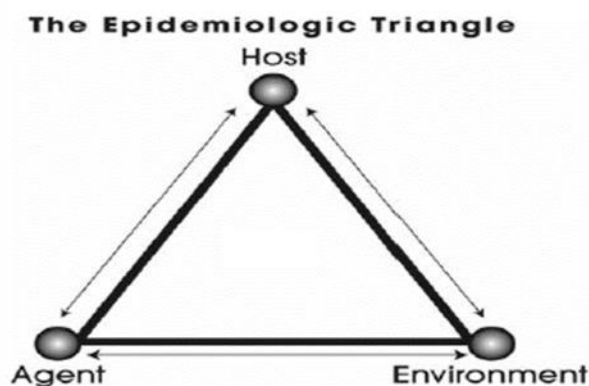
Methods of analysis of ATV data vary from study to study. Many studies are still aimed at understanding the fundamentals of ATV risk factors and the causal chain. Understanding the epidemiology of ATV injuries is essential for breaking the causal chain and reducing the injury rate.

2.8. Agent-Host-Environment Model

The Epidemiologic Triangle is a model originally created for studying the spread of infectious disease. The triangle developed into an epidemiologic and public health tool for studying the transmission of injury and illness. The Epidemiologic Triangle is composed of three

different parts: the agent, host, and environment. The interaction of the three aspects of the triangle can be used to systematically study the nature of the injury or illness (CDC). The first aspect of the triad, the agent, corresponds to the cause of the disease. In infectious disease applications, the agent is the virus or organism that causes the disease. The host aspect of the epidemiologic triangle corresponds to the host of the illness. The host is the characteristics of those exposed to the agent of the disease. Finally, the environment is the physical and social environment that leads to the development and the transmission and survival of the disease (CDC). The basic concept of the Epidemiologic Triangle, which initially was exclusively applied to the epidemiology of infectious disease process, was eventually applied to understanding the etiology of the injury process. “Accidental injuries and deaths follow some of the same biological laws as do disease processes, and are amenable to epidemiologic methods of study and prevention” (McFarland, 1955). See Figure 2.10 for an image of the Epidemiologic Triangle.

Figure 2.10. The Epidemiologic Triangle



From Centers for Disease Control and Prevention., 2013

Development of injury theory and prevention began in the early 20th century with the development of the National Safety Council in 1913. Prior to this time, injuries were not

considered a part of public health and were not researched due to the belief that injuries could not be predicted or controlled (Sleet, Dahlberg, Basavaraju, Marcy, McGuire, & Greenspan, 2011). The National Safety Council was founded to change this thinking by providing a clearinghouse for safety data.

In the next decade, Julian Harvey began to hypothesize how to control the causes of injuries and accidents. Harvey's program was called the three E's: education, engineering, and enforcement. (Sleet, Dahlberg, Basavaraju, Marcy, McGuire, & Greenspan, 2011).

In the 1940's Hugh De Haven began studying the mechanical energy and forces associated with injuries and prevention. De Haven's most famous publication, "Mechanical Analysis of Survival in Falls from Heights of Fifty to One Hundred and Fifty Feet" focused on understanding the "ability of the normal body to sustain very brief mechanical energy exchanges without fatal injuries" (Haddon, 1980). De Haven's early work with the mechanical forces preceded Gordon, Gibson, and Haddon's work on the application of the Epidemiologic Triangle to the study of injury process and prevention.

John Gordon was the first investigator who began to apply the triad to the determination of injury process as opposed to exclusively a tool to evaluate the transmission of disease (Songer). John Gordon, in his 1949 paper "The Epidemiology of Accidents" stated that "It is not so generally appreciated that injuries, as distinguished from disease, are equally susceptible to this (Epidemiological Triangle) approach, that accidents as a health problem of populations conform to the same biologic laws as do disease processes and regularly evidence comparable behavior" (Gordon, 1949). The application of a model to the injury process is of particular importance in that it gives scientists a tested method of classifying and defining the etiology of

accidents and injury. Prior to this time, there was no tool or model to study the epidemiology of injury.

While Gordon was credited with the application of the Epidemiologic Triad to injuries and accidents, James Gibson built upon the work of Gordon in that instead of using Gordon's perspective of the agent being the object involved in the injury, he developed the concept of the agent being the transfer of energy from the object to the host (Songer, n.d.). Later, it is this idea which would allow William Haddon to further develop and apply the Epidemiology Triad to injuries.

William Haddon is considered the father of modern injury epidemiology for his contributions to the field in the way of evaluation of injury process as well as intervention strategies (Runyan, 2003). Haddon created the Haddon Matrix, which is a method of looking at the Epidemiologic Triad of injuries at different points in the accident timeline. "A key element in Dr. Haddon's work was the contention that the epidemiologic framework could be used to identify risk factors for injuries. Moreover, these risk factors were not just those related to the host, but also those pertaining to the vehicle and the environment" (Songer, n.d.).

The Haddon Matrix is an extension of the Agent-Host-Environment model. Haddon extended the model to correspond to different phases in the sequence of the accident. 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. Haddon believed that "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 countermeasure can be undertaken" (Haddon, 1968). The following is a list of the three phases of social concern taken from Haddon's 1968 publication, "The changing approach to the epidemiology,

prevention, and amelioration of trauma: the transition to approaches etiologically rather than descriptively based.”

1. Prevention of mechanical forces above injury thresholds
2. Interaction of mechanical forces on the host
3. Maximizing Salvage.

In 1973 Haddon continued to expand upon his original ideas and developed 10 countermeasures which could be applied to different phases or boxes in his matrix. The following list of countermeasures, first applied by Haddon, was proposed in order to prevent or limit the transfer of energy from the source to the human, therefore preventing or limiting the potential for injury or death.

1. Prevent the Creation of the Hazard
2. Reduce the amount of hazard brought into being
3. Prevent the release of the hazard
4. Modify the rate of release of the hazard from its source
5. Separate the hazard from that which is to be protected by time and space
6. Separate the hazard from that which is to be protected by a physical barrier
7. Modify relevant basic qualities of the hazard
8. Make what is to be protected more resistant to damage from the hazard
9. Begin to counter damage done by the hazard
10. Stabilize, repair and rehabilitate the object of damage (Haddon, 1995).

These generalized countermeasures were designed to be applied after the Haddon Matrix has been completed for the designated accident type. By developing his countermeasures, Haddon came full circle in the progression of injury epidemiology. Not only did he create a model to evaluate the hazards of the accident, but also developed a set of solutions that could be applied to risks associated with that injury event. According to Thomas Songer, benefits of the Haddon Matrix include: recognizing injury as a process, providing a multi-disciplinary approach to thinking about the injury process, development of creative solutions, and identification of prevention as well as resource allocation strategies. See Figure 2.11 for an image of the Haddon Matrix.

Figure 2.11. The Haddon Matrix

COMPONENT \ PHASE	DRIVER	PASSENGERS	PEDESTRIANS	BICYCLISTS	MOTOR-CYCLISTS	VEHICLES	HIGHWAYS	POLICE
PRECRASH								
CRASH								
POSTCRASH								

TIME ↓

RESULTS →

DRIVER INJURY & DEATH PASSENGER INJURY & DEATH ----- ----- --- PROPERTY DAMAGE ----- -----

From Haddon, 1968

The purpose of using the agent-host-environment model in injury epidemiology has several facets, ranging from providing a scientific basis for the study of injury epidemiology, evaluation of the etiology accidents, to formation of creative prevention strategies. Haddon believed that “It is the shift from descriptive thinking and nosology to categorizations in etiologic terms. In the past, this shift has almost invariably been accompanied by increasingly successful control efforts.... Hence it opens the door to the possibility of manipulation and control” (1968). “Such an analysis can provide the basis for highly specific programs of accident prevention since the epidemiologic concept of causation emphasizes the role of multiple causes in accidents... (it) is also useful in revealing the relative importance and urgency of various aspects of the accident problem” (McFarland, 1955). “Each of these cells (of the Haddon Matrix) represents an

opportunity to think through the prevention possibilities and encourage you not to devote all of your attention to one or two cells in on the matrix” (Songer, n.d.).

The Agent-Host-Environment model is useful to the field of epidemiology in that it can be applied to many different subsections and circumstances. This model can be applied as a case study to a specific accident or in aggregate to a collection of accidents in order to analyze the most prevalent contributing risk factors. The identification of risk factors has opened the door to analysis of the success of interventions and the changing risks as technology and society progress. When writing on the challenges of injury prevention in the coming years, Sleet et al. (2011) comment, “Because most injuries are now considered preventable, the challenges lie in identifying those injury and violence winnable battles and in developing effective policies and delivering effective programs that can save many more lives”(Sleet et. al., 2011).

3. Experimental Methods and Materials

3.1.Data Source

The data source for this study was provided by the U. S. Consumer Product Safety Commission under the Freedom of Information Act (FOIA). An online request was sent to the CPSC for all Injury and Accident Reports for the years 2011-2013. As a result of the request, the CPSC returned two different types of incident reports, In-Depth Investigation Files (INDP), and Injury/Potential Injury Accident Files (IPII). INDP files are investigations that have been further investigated by the CPSC based on interviews or on-scene investigations. IPII files contain not only accidents and deaths, but hotline reports, consumer complaints, and letters to the CPSC. The latter type of file has not been further investigated by CPSC investigators. For the purpose of this study, the INDP accounts were the chosen type of file.

The CPSC identifies incidents for investigation from a variety of different sources. The main sources of incident reporting are News Reports, Death Certificate Files (DTHS), and the Medical Examiners and Coroners Alert Project (MECAP). Once identified, these reports are investigated by CPSC personnel either by phone, onsite, or other method. The majority of investigations were identified by News Report and then investigated by means of a phone interview.

3.2.Data Sample

A total of 1,230 INDP reports were obtained for the years 2011-2013. These reports were numbered and ordered first by state in which the incident occurred and then by date of the accident report. Each INDP report contains a coded section related to the source of the report and investigation as well as demographic information. After the demographic information, a brief

narrative report contains additional information on the nature of the crash as well as additional information obtained during the investigation.

Reports contain the following coded fields: Incident Number, Source (of report), Type (of investigation), Status (of investigation), Incident Date, Date Entered, City/State, Location (type), Age/Sex, DISP (Disposition of Injured Person), Diagnosis, and Body Part. The narrative accounts may contain information on type of accident, events leading up to the accident, presence of alcohol or drugs, other vehicles involved, excessive speed, safety equipment, and other notable information. Not all narrative accounts contain all of the above information, leaving many accounts with unknown contributing factors.

Based on the narrative and code fields, the following variables were created: Season, Region, Age Range, Age (Less than 16, 16-64, or Greater than 64), Occupational Related, Passenger or Driver, Number of Users on ATV, Helmet, Alcohol or Drug Use, Presence of Mechanical Failure, Excessive Speed, Type of Accident, Other Vehicle Involved, and notes about the Terrain.

3.3.Data Collection

Each INDP report was read and then manually coded into a Microsoft Excel File. Each row of the file represented a separate case number and columns represented information contained in the report. The following are the columns contained in the file: Number, Date, Season, Region, State, City, Source, Type of Follow-Up, Location Type, Age, Sex, Disposition, Diagnosis, Body Part, Driver or Passenger Status, Number of Users on ATV, Helmet, Alcohol or Drugs, Mechanical or Design Failure, Excessive Speed, Type of Accident, and Other Vehicle Involved.

3.4. Case Definitions

For variables that were up to the interpretation of the reader/coder, a decision tree matrix was used in order to ensure consistency across cases. Decision trees were used to determine the following variables: Mechanical or Design Failure, Excessive Speed, Type of Accident, Other Vehicle Involved, and if the event should be considered an occupational related injury. The decision trees that were used in the coding of the narrative responses can be found in Appendix II.

3.5. Fitting the Agent-Host-Environment model

In order to apply the Agent-Host-Environment epidemiological model to each case, response variables taken from the demographic and narrative sections were categorized as pertaining either to the agent, host, or environment.

Variables pertaining to the host (ATV User) involved in the accident included: Age, Sex, status as the Driver or Passenger of the ATV, Helmet, and presence of Alcohol or Drugs.

Variables pertaining to the agent (the ATV) involved in the accident included: Mechanical or Design Failure, Excessive Speed, and Type of Accident.

Variables pertaining to the environment (Physical or Social) involved in the accident included: Date, Season, Region, Location type, whether or not the event was occupational in nature, Number of Users on ATV, and Other Vehicle Involved.

Additional variables include information relating to the injury. Body part injured, diagnosis, and disposition were all variables related to the outcome of the injury event. For the purposes of this report, only injuries with a disposition of Dead on Arrival (DOA) were used.

3.6.Data Analysis and Statistical Methods

3.6.1.Haddon Matrix for ATV Injuries

Variables identified during a review of the literature as well as analysis of the INDP narrative reports were used to construct a Haddon Matrix for ATV Injuries. Variables were separated as pertaining to the Host, Agent, Physical Environment, or Social Environment. These variables were then separated based on phase of injury event: pre-event, event, or post-event.

3.6.2.Demographic Data

Descriptive statistics were calculated using SAS 9.3. Frequency statistics were calculated for categorical variables and univariate analysis were performed on continuous variables. Chi-square tests for equal proportions were performed for the following variables: sex, region, and season.

3.6.3.Incident Rate Calculations

Incident rates were calculated for different populations of interest in order to determine if differences exist between different population groups, as well as to serve as a method of comparison against different studies. The first incident rate was the overall rate of ATV injury per 100,000 population/year. This incident rate was calculated using the number of narrative mortality reports (n=1,193)/3 in order to get the average number of fatalities per year. The 2010 census estimate for resident population was used as the denominator for this rate calculation.

To understand the role of occupational use of ATVs, the incident rate for the agricultural population was calculated. This rate was calculated by using cases identified with a location type as farm per 100,000 farming population/year. The farming population was estimated using the 2012 Census of Agriculture data. The farming population was estimated as the total number of

farm operators added to the total number of hired farm workers, in addition to the total number of unpaid farm workers.

Incident rate per ATV was calculated using data from the 2012 Annual Report of ATV-Related Deaths and Injury published by the CPSC. The CPSC estimates that 10.7 million ATVs were in use in the year 2011.

Incident rates were calculated for gender as well as population aged 65 and older. Denominator data for these calculations was taken from the 2010 Census based on the Residential Population.

3.6.4. Classification and Regression Trees

After performing basic descriptive statistics, a Chi-Square Automatic Interaction Detector (CHAID) analysis was performed using JMP Pro 11. This analysis tool was used in order to identify characteristics associated with different outcomes or variables. A CHAID analysis sets on variable as the dependent characteristic with all other variables and independent predictors. The classification tree, created by the analysis, models the relationship between the dependent and independent variables. This method allows for identification of a priority of independent variables in predicting the dependent characteristic. Partitioning of categorical data is performed based on the G^2 statistic and calculated LogWorth where $\text{LogWorth} = \log(\text{p-value})$ (SAS Institute Inc., 2014).

The CHAID analysis was used to create six different trees based upon the following variables: Helmet Use, Alcohol and Drug Use, Accident Type, Body Part Injured, Diagnosis, and Location Type. Only variables categorized as host, agent, or environment were used as predictor variables. The classification trees had a minimum group size of 25 and cases with an unknown value for the dependent characteristic were removed from the analysis. Based on a

recommendation in the literature, trees were split until the LogWorth of the split was less than or equal to two (SAS Institute Inc., 2014). A LogWorth of two corresponds to a significant p-value of .01.

After creation of the classification trees, each partition was categorized as a host, agent, or environment division. By categorizing the partitions, it is possible to visualize which classification of variables lead to the assigned dependent variable and if overlap exists between host, agent, and environmental factors.

4. Results

4.1. Haddon Matrix for ATV Injuries

Based on review of current literature as well as analysis of the narrative INDP reports, a Haddon Matrix was compiled based on different areas of risk. Figure 4.1 contains the completed Haddon Matrix for ATV injuries and fatalities. Factors are separated as pertaining to the host, agent, or physical/social environment. Furthermore, factors were separated based on which phase of the event they relate to: pre-event, event, or post-event. Several factors are present in more than one cell of the table due to their impact during multiple phases of the event or their impact to more than one type of the environment. For example, presence of multiple vehicles in the pre-event phase may offer the opportunity for collisions (physical environment) and may also be a social driver for racing or erratic driving behaviors.

Figure 4.1. Haddon Matrix for ATVs

	HOST	AGENT	PHYSICAL ENVIRONMENT	SOCIAL ENVIRONMENT
PRE-EVENT	<ul style="list-style-type: none"> •Alcohol/Drug Use •Training •Experience •Age •Sex •Height/Weight Ratio •Physical Limitations 	<ul style="list-style-type: none"> •Size/Power of ATV •Use of Governors •Modifications to ATV •Carrying Loads •Carrying Passengers 	<ul style="list-style-type: none"> •Lighting Conditions/ Time of Day •Weather Conditions •Speed Limits •Multiple Passengers •Multiple Vehicles •Season 	<ul style="list-style-type: none"> •Multiple Passengers •Multiple Vehicles •Marketing campaigns •Appropriate Labeling of ATV Hazards •Supervision of Youth •Availability of Training •Affordability of PPE
EVENT	<ul style="list-style-type: none"> •Helmet/ PPE Use •Age 	<ul style="list-style-type: none"> •Type of Accident •Excessive Use of Speed •Presence of a Mechanical Failure 	<ul style="list-style-type: none"> •Obstructions in Road or Path •Steep/Unsuitable Terrain •Location Type 	<ul style="list-style-type: none"> •State legislation on Helmet Use •State legislation on street/highway use and speed limits •State legislation on Age Limitations •Enforcement of legislation
POST-EVENT	<ul style="list-style-type: none"> •Co-Morbid Conditions •Age •Medications •Willingness/ability to seek medical care 	<ul style="list-style-type: none"> •Rider Separation from Path of ATV 	<ul style="list-style-type: none"> •Availability of Emergency Medical Care •Availability of Rehabilitative Facilities 	<ul style="list-style-type: none"> •Detection of an Injury Event •Investigation of Event and Causal Factors •Documentation of Event

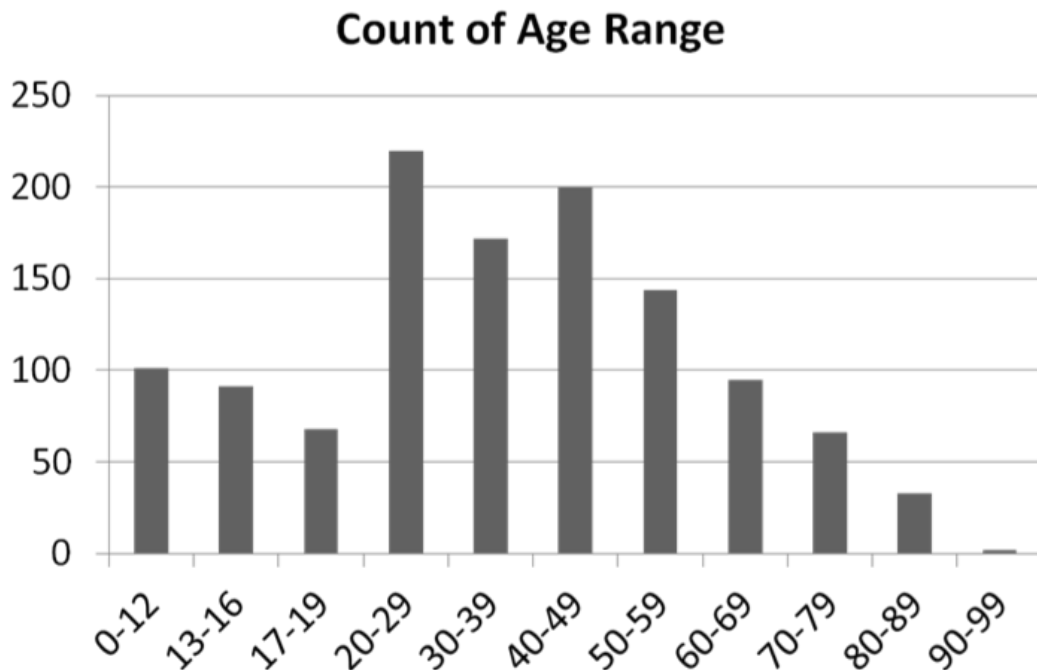
4.2. Demographic Data

4.2.1. Descriptive Statistics

After cleaning the data, a total of 1,193 reports remained. Due to a limited number of narrative reports containing reports of mortality, reports were excluded from the data set if they contained a disposition other than DOA.

Basic demographic statistics were calculated for each narrative report. Mean age at time of death was found to be 37.97 (SD=20.24, n=1192). Ages were separated into the following categories: less than 16, 16-64, and greater than 64. Of the sample, 14.01% were less than 16 (n=167) and 12.16% were greater than 64 years of age (n=145). See Figure 4.2 for further age division.

Figure 4.2. Number of Cases by Age Range



Of the 1,193 reports, 84.58% were male. A Chi-Square test for equal proportions revealed significance for gender differences, $\chi^2(1, N = 1,193) = 570.52, p < .0001$.

Season and regional differences also exist in the number of INDP reports completed in the years 2011-2013. A Chi-Square test for equal proportions revealed significance in both the number of reports by season and region, $\chi^2(3, N = 1,193) = 216.71, p < .0001$ and $\chi^2(3, N = 1,191) = 355.95, p < .0001$, respectively. See Figures 4.3 and 4.4.

4.2.2. Agent-host-environment results and tables

Variables were separated as host, agent, environment, or injury and are presented in Table 4.1.

Figure 4.3. Number of Cases by Season

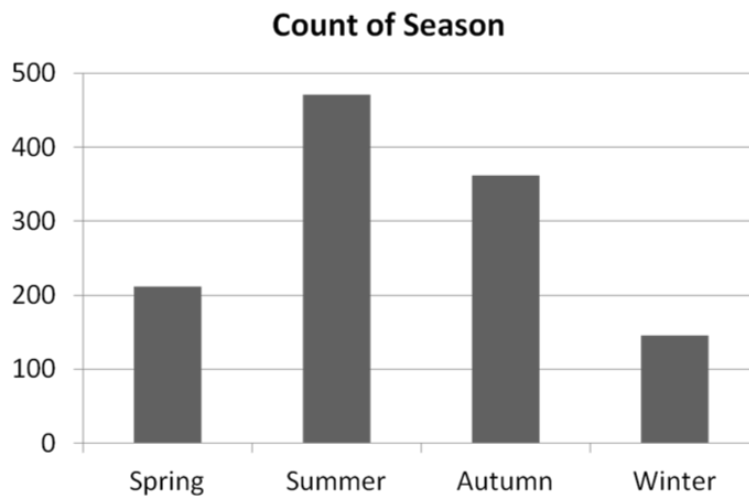


Figure 4.4. Percentage of Cases by Geographic Region

Percentage of Reports by Region

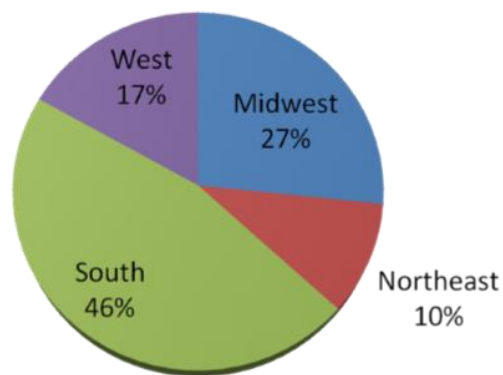


Table 4.1. Demographic Statistics

Host Variables (ATV User)	Percent (N) N(Total)=1193	Agent Variables (The ATV)	Percent (N) N(Total)=1193	Environment Variables (Physical or Social)	Percent (N) N(Total)=1193	Injury Variables	Percent (N) N(Total)=1193
Gender Male Female	84.58% (1009) 15.42% (184)	Type of Accident Collision Overturn Ejection Unknown/Other	42.92% (512) 37.38% (446) 11.74% (140) 7.96% (95)	Season Spring Summer Autumn Winter Unknown	17.80% (212) 39.55% (471) 30.39% (362) 12.26% (146) (2)	Diagnosis Internal Injuries Other Fracture Anoxia Crushing	68.15% (813) 12.99% (155) 6.79% (81) 6.37% (76) 5.70% (68)
Age Less than 16 16-64 Greater than 64 Unknown	14.00% (167) 73.76% (880) 12.24% (145) (1)	Excessive Speed Yes No Unknown	84.30% (188) 15.70% (35) (970)	Region South Midwest West Northeast	46.35% (553) 26.66% (318) 16.85% (201) 10.14% (121)	Body Part Injured Head Multiple Upper Trunk Neck Lower Trunk Leg Unknown	59.98% (655) 17.03% (186) 16.48% (180) 4.67% (51) 1.65% (18) 0.18% (2) (101)
Driver or Passenger Driver Passenger Unknown	91.12% (1078) 8.88% (105) (10)	Mechanical Failure Yes	1.68%(20)	Location Type Street Home Farm Public Sports Industrial Unknown	58.26% (684) 12.78% (150) 12.69% (149) 9.63% (113) 5.88% (69) 0.77% (9) (19)		
Helmet Yes No Unknown	11.85% (96) 88.15% (714) (383)			Occupational Use Yes No/Unknown	3.10% (37) 96.90% (1156)		
Alcohol or Drug Use Yes No Unknown	84.27%(241) 15.73% (45) (907)			Number of Users on ATV 1 2 3 4 5 Unknown	79.69%(938) 18.27% (215) 1.44% (17) 0.51% (6) 0.08% (1) (16)		
				Other Vehicle Involved No Auto ATV Other Unknown	85.37% (945) 10.12% (112) 3.43% (38) 1.08% (12) (86)		

4.3. Incident Rates

Table 4.2. Incident Rate Calculations

	Numerator Data	Denominator Data	Incident Rate
Overall IR	397.67 Average Number of ATV Fatalities per year (2011-2013) based on CPSC Investigations	308,746,000 Total US Resident Population (2010 Census Data)	.13 per 100,000 Population/year
IR Farming Population	49.67 Average Number of ATV Fatalities occurring on farms per year (2011-2013) based on CPSC Investigations	8,031,786 2012 Census of Agriculture (Operators +Hired Labor+ Unpaid Workers)	.62 per 100,000 Population/year
IR per ATV	397.67 Average Number of ATV Fatalities per year (2011-2013) based on CPSC Investigations	10,700,000 (CPSC Estimate in 2011)	3.72 per 100,000 ATVs/year
IR Males	336.33 Average Number of male ATV Fatalities per year (2011-2013) based on CPSC Investigations	151,781,000 Total US Resident Population (2010 Census Data)	.22 per 100,000 Population/year
IR Females	61.33 Average Number of female ATV Fatalities per year (2011-2013) based on CPSC Investigations	156,964,000 Total US Resident Population (2010 Census Data)	.04 per 100,000 Population/year
IR Age 65 and Older	48.33 Average Number of ATV Fatalities in the age group 65 and older per year (2011-2013) based on CPSC Investigations	40,268,000 Total US Resident Population (2010 Census Data)	.12 per 100,000 Population/year

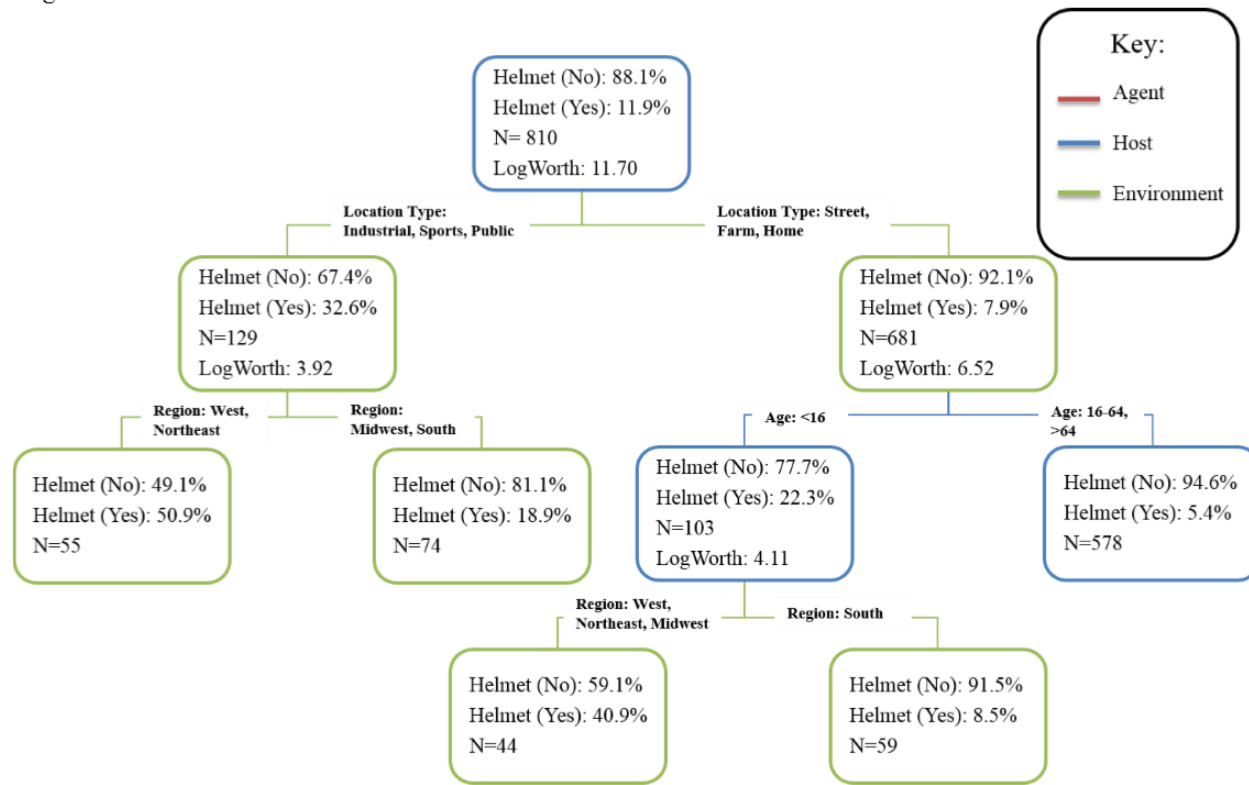
4.4.CHAID

The following sections provide an analysis of the associations between the predictor variables and a chosen dependent variable. The dependent variables chosen were: helmet use, alcohol and drug use, accident type, body part injured, diagnosis, and location type. These dependent variables were chosen, at least one from each aspect of the epidemiologic triad, in order to understand the influence that each aspect of the triangle has on the other vertices or on the outcome variables of body part injured and diagnosis. In addition, these variables were chosen as a focus due to their ability to be compared with results of previous studies.

4.4.1.Helmet Use

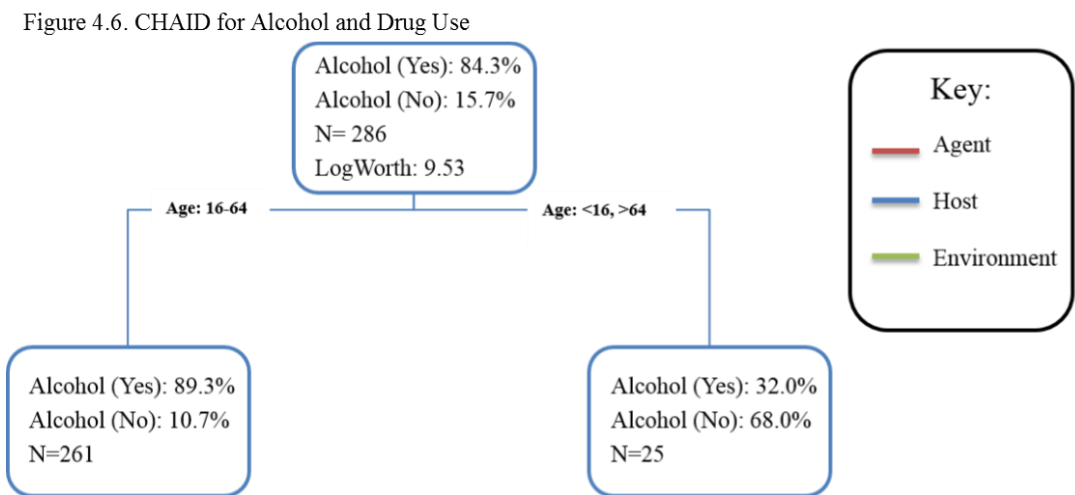
The covariate most strongly associated with helmet use was location type; users in the home, street or farm were less likely to wear helmets than users in other locations (industrial, sports, or public venues) (LogWorth=11.70, $p<.01$). Overall helmet use prevalence in fatal LOC events was 11.9%. Users in the farm, street and home wore helmets in 7.9% of cases, compared to users in industrial, sport, or public areas who wore helmets in 32.6% of cases. Users most likely to have worn helmets were those in public, sports, or industrial locations in the West or Northeast regions, where the prevalence of wearing a helmet was 50.9% compared to only 18.9% of users in the Midwest or South regions. After four significant partitions, determined by a minimum LogWorth=2 ($p=.01$), the user demographic least likely to have worn helmets were users operating in the location types of home, street, or farm, over the age of 15. Of users in this cohort, only 31 of 578 (5.4%) were wearing helmets at the time of mortality, compared to the user demographic most likely to wear helmets, where 28 of 55 (50.9%) wore helmets at the time of mortality. See Figure 4.5 for the partition based on helmet use.

Figure 4.5. CHAID for Helmet Use



4.4.2. Alcohol and Drug Use

A total of 286 CPSC INDP reports contained information on the use of alcohol or drugs at the time of the LOC event. As seen in Figure 4.6, the only covariate showing a significant association with alcohol or drug use was age group. Users in the age group of 16-64 were significantly more likely to have used alcohol or drugs at the time of LOC than users under the age of 16 or over the age of 64 (LogWorth= 9.53, $p < .01$). Users in the age group of 16-64 had documented alcohol or drug use in the incident reports generated by the CPSC in 233 of 261 cases (89.3% of the time), in comparison to users of the youngest and oldest age groups, having documented alcohol or drug use in 8 of 25 cases (32% of cases).



4.4.3. Accident Type

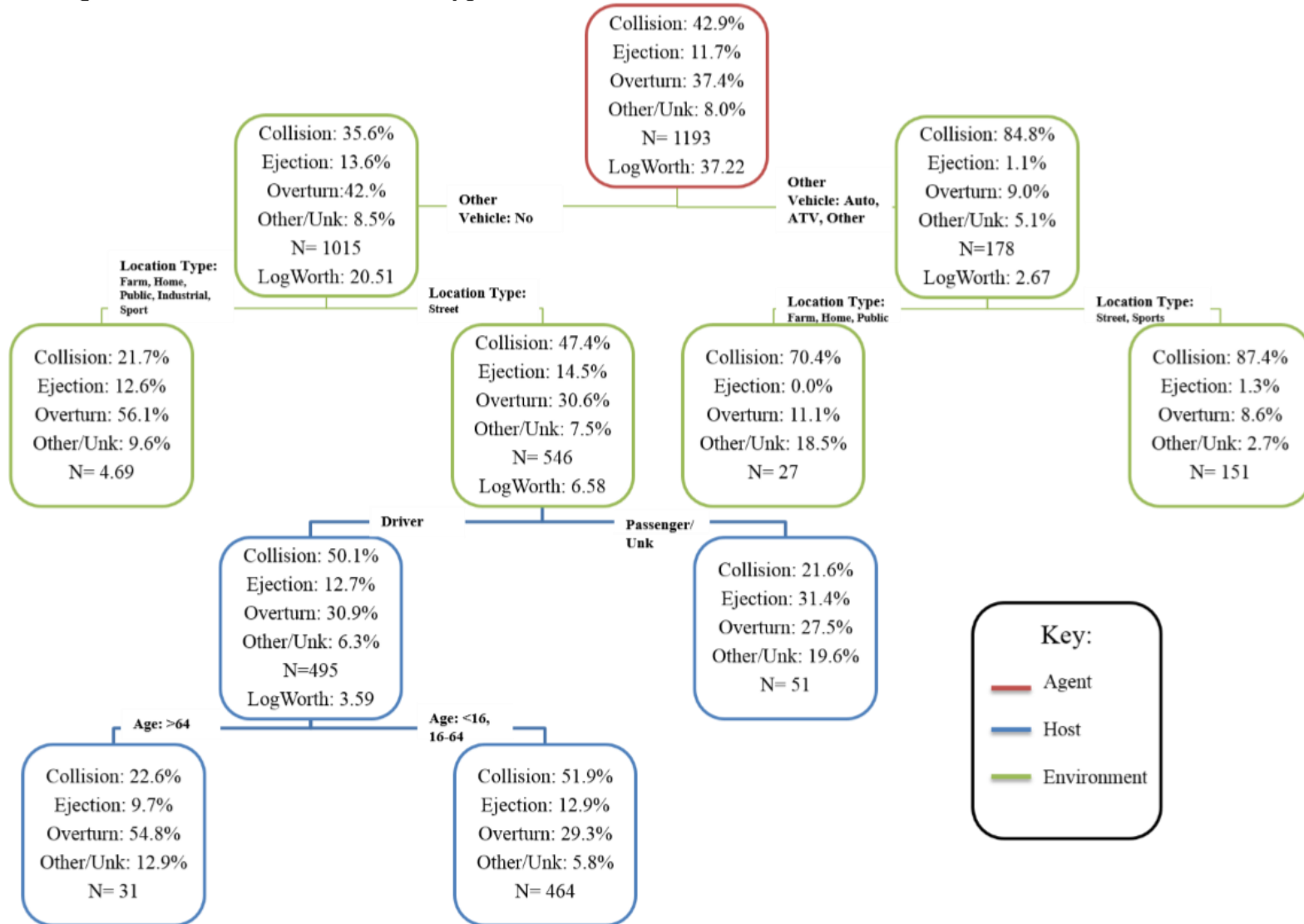
The covariate most strongly associated with accident type was another vehicle's involvement in the LOC event. Accidents were significantly more likely to be a collision-type event if another vehicle was involved (LogWorth=37.22, $p < .01$). Additionally, collisions were the most common

accident type when another vehicle was involved and the location was on the street or in a sport location. In this cohort, 132 of 151 (87.4%) of cases were collision-type events.

When another vehicle was not involved in the LOC event, location type was a significant covariate associated with accident type (LogWorth=20.51, $p<.01$). When the fatality occurred on the street there was a higher prevalence of collision and ejection-type events (47.4 and 14.5% of cases) and a lower prevalence of overturn type events (30.6% of cases), compared to fatal LOC events at all other location types (home, farm, sport, industrial, and public) having a higher prevalence of overturn-type events (56.1% of cases), and a lower prevalence of collision and ejection type events (21.7 and 12.6% of cases).

Ejection-type events had increased prevalence in cases where the fatal user was the passenger of the ATV. As shown in Figure 4.7, when another vehicle was not involved in an event occurring in the street, the prevalence of fatal ejections for a passenger was 31.4%, while the prevalence of fatal ejection for drivers was 12.7%. A further significant split of this cohort reveals that drivers over the age of 64, had a fatal overturn prevalence of 54.8%, in comparison to those under the age of 65 whose prevalence of fatal overturn was 29.3%.

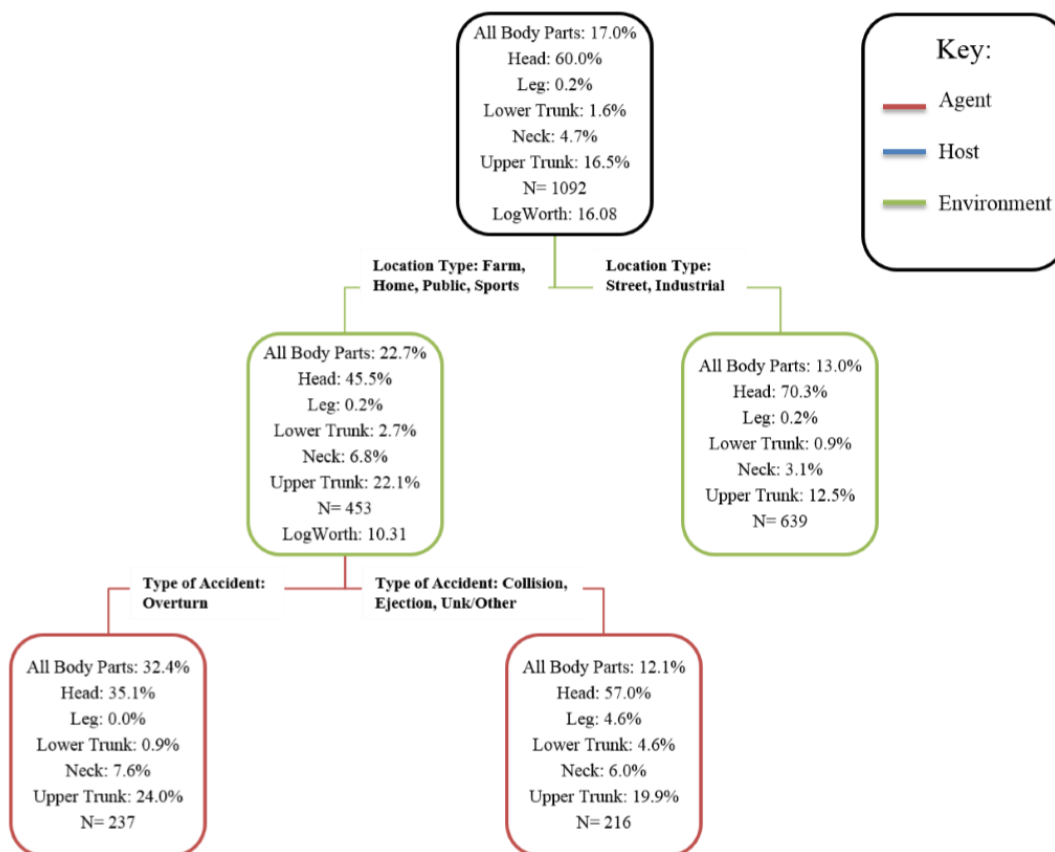
Figure 4.7. CHAID for Accident Type



4.4.4. Body Part Injured

Figure 4.8 contains the CHAID analysis for body part injured during the ATV LOC event. The covariate most strongly associated with body part injured was location type (LogWorth=16.08, $p < .01$); users who operated in the street or in industrial areas had a higher prevalence of head injuries (70.3% of cases) in comparison to those who operated on the farm, at home, or in public or sports areas (45.5% of cases). After significant partition of fatalities in the cohort of farm, home, public or sports location types by type of accident, injuries to all body parts and the upper trunk had a higher prevalence in overturn-type events (32.4 and 24% of cases) than other accident types with a prevalence of 12.1% to all body parts and 19.9% to the upper trunk (LogWorth=10.31, $p < .01$).

Figure 4.8. CHAID for Body Part Injured



4.4.5. Diagnosis

As shown in Figure 4.9, the covariate most strongly associated with diagnosis was accident type. Accidents classified as a collision or ejection had a lower prevalence of anoxia, crushing, or other diagnosis than overturn or other-type accidents (LogWorth=19.12, $p < .01$). The highest prevalence of anoxia (19.0%) occurred in the cohort of cases with a location type of farm or home and with an accident type of overturn or other. The highest prevalence of crushing injuries (14.5%) occurred in the cohort of collision or ejection type events, in the Midwest and Southern regions, with a location type of farm or public land. Internal injuries were classified as the fatal diagnosis in 68.1% of all cases.

4.4.6. Location Type

The covariate most associated with location type at time of mortality was type of accident. Users who were involved in a collision or ejection type event were more likely to be operating on the street (72.1%) than users involved in an overturn or other-type event (41.1%) of cases (LogWorth=19.12, $p < .01$). The cohort with the largest percentage of cases taking places at the home and farm were users in overturn and other-type events, under the age of 16 or over the age of 64. In this cohort, 65% of cases occurred on the farm or at home, compared to the overall average of 25.5% of cases taking place at these location types. See Figure 4.10 for the partition based on location type.

Figure 4.9. CHAID for Diagnosis

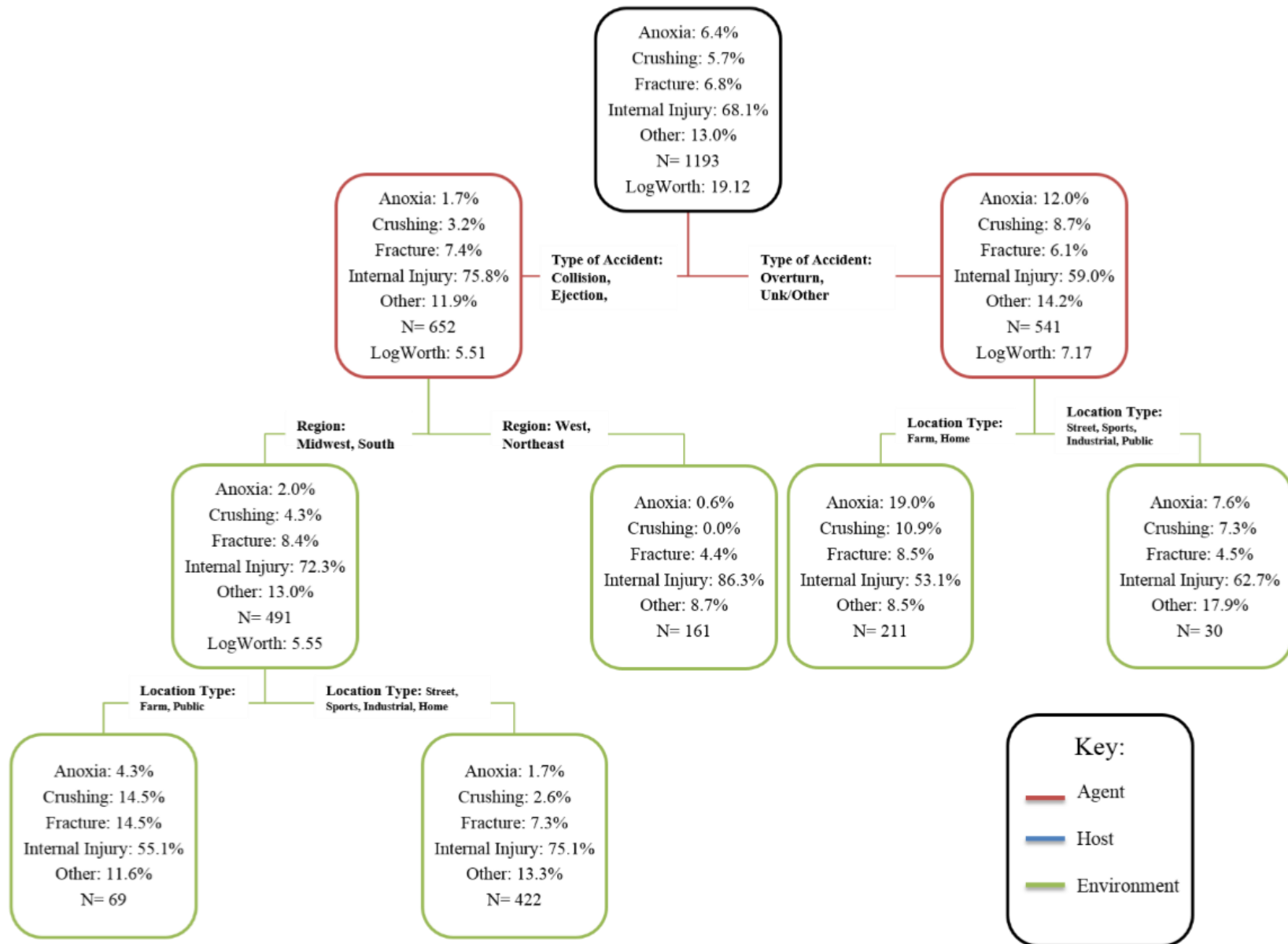
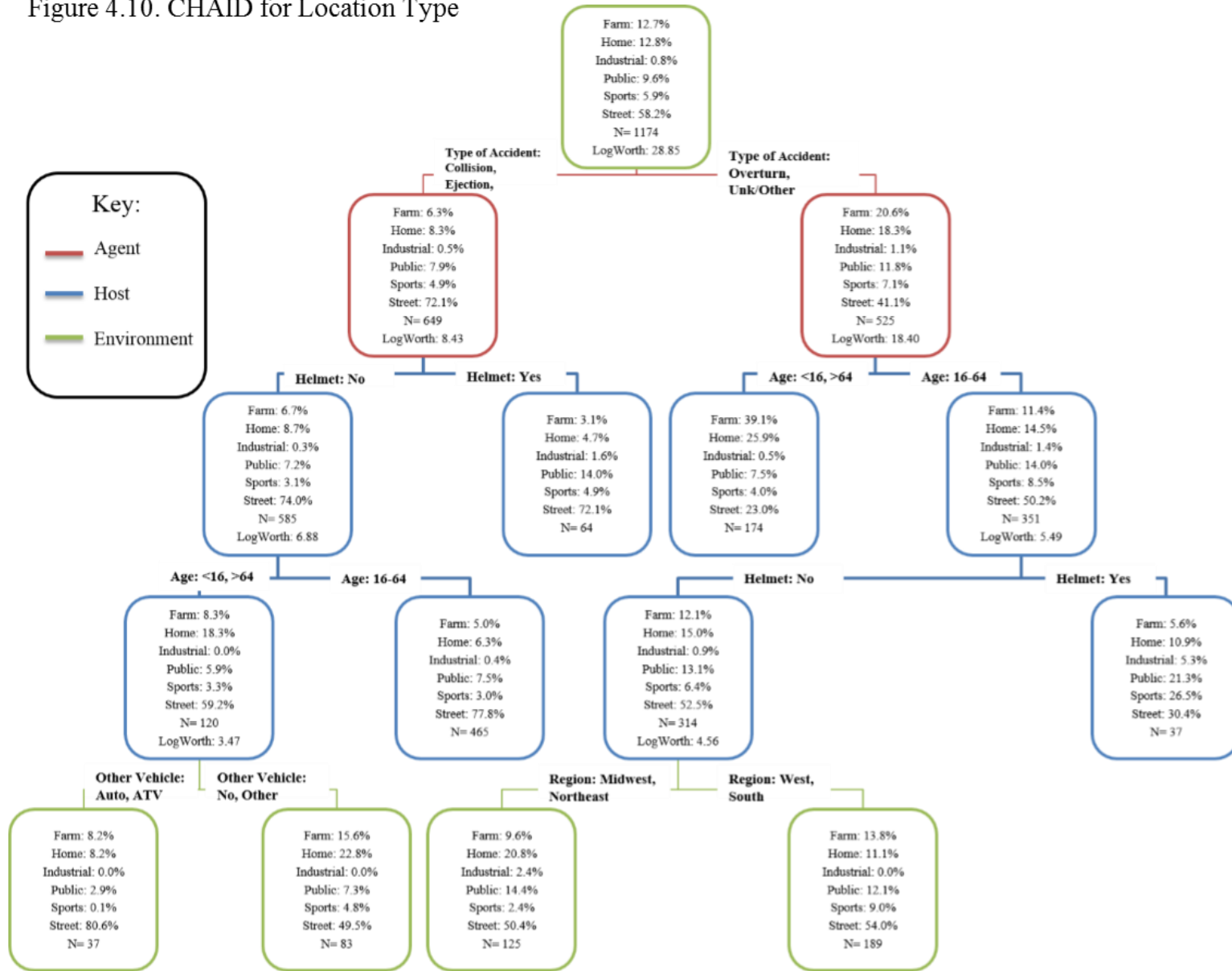


Figure 4.10. CHAID for Location Type



5. Discussion

The present study explores the demographics and associates between risk factors of fatal ATV LOC events.

5.1. Discussion of Results

5.1.1. Host Factors

Factors classified as a pertaining to the host aspect of the epidemiologic triangle are an indication of the human element of LOC events. Studying prevalence of traumatic injuries and fatalities in children has always been of concern in order to enact and study appropriate intervention strategies. Recently, the analysis of ATV injury rates is of interest due to the legislative changes made by the 2008 CPSIA which regulates the sale of ATVs to youth operators. Helmkamp, using data from 2000-2005, before the 2008 CPSIA, found that children (under the age of 16), accounted for 20% of ATV fatalities during these years (Helmkamp, 2009). This data contained in this report, which used data from the years 2011-2013, found that children accounted for 14% of ATV fatalities during these years. While not a direct measure of the success of the 2008 CPSIA, it may be a lagging indicator of the success of ATV regulation and safety programs.

The high ratio of male to female deaths is not unique to the data contained in this report. Helmkamp, in his 2012 report on *State-Specific ATV-Related Fatality Rates*, used data from 2000-2007 and found 86% of ATV deaths were male, a number strikingly similar to the results contained in this report where 85% of fatalities were male.

Figure 4.5 demonstrates that the factor most associated with helmet use is location type, with users on the farm, home or street less likely to wear helmets than other location types.

Interestingly, it is an environmental factor, location type that has the strongest association with the host variable of helmet use. Users who operate on the farm or home may be less likely to wear helmets due to their use of ATVs for occupational purposes (O'Connor, Hanks, & Steinhardt, 2009). Occupational users may be less likely to wear helmets due to the perception of PPE being designed exclusively for recreational users as well as the perception that helmets are cumbersome and make performing occupational activities difficult. In addition to perception, according to a summary of state legislation requirements for ATVs in 2009, three states, Kentucky, Washington, and Wisconsin, had helmet requirements for users, however operators using the ATV for agricultural activities were exempt from the mandatory helmet laws (SVIA, 2009). Other states have helmet use regulations that are only in effect in areas of public land or for users under the age of 18. This may contribute to the higher helmet use prevalence in public, industrial, or sports location types over private land.

Fortunately, Figure 4.5 also shows a significant difference in the prevalence of helmet use between users under the age of 16 versus users 16 and older who operate on the street, farm, or at home. This may be attributed to the some states enacting legislation requiring helmets for users under the age of 16, or perhaps as a result of efforts of the 2008 CPSIA.

As shown in Figure 4.6 the only significant factor with alcohol and drug use is age group. Users ages 16-64 have a higher prevalence reported alcohol and drug use, this may be due to the legality and ease of access to alcohol for the majority of this group. In addition, there may be decreased prevalence in the age groups of less than 16 or greater than 64 due to investigations and reports less likely to consider alcohol and drug abuse in these age groups.

5.1.2. Demographics Host Injury v. Fatality

Demographic statistics compiled in this report were based exclusively on fatality cases. Comparison between the demographics of injury cases versus fatality cases was accomplished using 2010 CPSC data on ATV-Related Emergency Department Treated Injuries (Garland, 2014). The injury database, and summary data contained in their report, found that their sample of injury cases contained 69.4% male victims with 20.9% of injuries being youth under the age of 16. In comparison to the data presented in this report, fatality cases were 84.6% male and 14.0% of victims were less than 16 years of age. Stark differences arise when comparing injury types between the two groups. In the CPSC injury report, 27.2% of cases were diagnosed as a head injury, while head injuries were cited as the body part injured in nearly 60% of fatalities. Prevalence of extremity injuries is much higher in non-fatal LOC events.

The findings of this report when compared to the statistics generated by emergency department treated injuries suggest that fatal events are more likely to occur during recreational activities. Statistics of emergency department treated injuries show ATVs were being used for occupational purposes in 11.1% of injury cases (Garland, 2014) while the results in this report indicate occupational ATV use in 3.1% of fatality cases.

While the comparison between the demographics of non-fatal and fatal injuries is interesting, it is hardly surprising. Gender differences between injury and fatality cases may be explained by risk taking behaviors found in the male populations. Males are more likely take risks that will result in injury (Helmkamp, 2009), and, as seen in this report, have LOC events that are more likely to end in fatality. Therefore, the heightened male demographic in fatality cases is hardly unusual.

Interestingly, the percentage of youth in the population of ATV fatality cases is lower than the percentage of youth in the population of ATV injury cases. This may be for several different reasons, some of which may be due to promising effects of legislation. The 2008 CPSIA enacted several policies with the goal of preventing youth injuries and increasing the overall safety of ATVs. These preventative measures included prohibiting the sale of adult sized ATVs for use by youth, new training programs, as well as several marketing campaigns promoting adult supervision of youth riding and proper PPE (Catenacci, 2009; Fleming, 2010; Rodgers & Adler, 2001; Helmkamp et al., 2009). Limiting the speed and power of youth ATVs may have a protective effect by inhibiting creation of an agent (mechanism) possible of producing forces resulting in mortality. However, it is impossible to exclusively credit the prevention measures of the CPSC; the lower fatality rate may be due to the absence of comorbid conditions found in the aging population which prevents successful recovery from similar traumatic injuries in other age groups.

5.1.3. Agent/Injury Discussion

The most significant factor associated with the type of LOC event was whether or not another vehicle was involved in the incident (Figure 4.7). Events occurring on the street, sports or industrial areas had a higher prevalence of collision-type events and all other location types had a higher prevalence of overturn type events. The higher prevalence of collision type events in the location of street and sports may be due to the increased vehicle traffic seen at these locations over the location types of farm, home, and public. The higher prevalence of overturn type events on the farm and home may be due to use of the ATV to carry heavy loads to accomplish occupational activities or perhaps the installation of aftermarket alterations to the

body of the ATV (OHSA, 2006). These occupational alterations may affect the center of gravity of the ATV, making it more prone to rollovers (OHSA, 2006).

The above discussed factors, other vehicle involved and location type, had the most significant associations with LOC event type. Interestingly they were both related to the environmental aspect of the epidemiologic triangle. As LOC event type is the only agent factor, the environmental aspect of the epidemiologic triangle has the strongest influence on the agent phase of the triangle.

The only host-related factor with a significant association to the type of LOC event is age group. The age group of over 64 years of age has a higher overturn prevalence than the other age groups (Helmkamp & Carter, 2009). This may be due to users in this age group having enough strength and coordination to appropriately operate an ATV. Correct operation of an ATV involves the entire body, with significant attention paid to appropriate leading and shifting of body weight. Helmkamp discusses these challenges in his 1999 article titled *All-terrain Vehicle Deaths Among the West Virginia Elderly, 1985 to 1998*. Helmkamp cites that conditions such as poor vision, and reduction of muscle strength and coordination lead to differences in crash dynamics than younger users (Helmkamp, 1999).

Figure 4.8 diagrams the association between the body part involved in the fatal LOC event and the location type, an environmental factor, and type of LOC event, an agent factor. The location types of street and industrial areas had an increased prevalence of head injuries in relation to events occurring on the farm, at home, public or sports locations. The latter locations see an increased prevalence of injuries to all body parts as well as the upper trunk. Injuries to all body parts, such as asphyxia, and the upper trunk (thorax) are more likely to be a result of an overturn event (Rechnitzer, Grzebieta, McIntosh, & Simmons, 2013). This significant finding is

seen with the next level of association, as overturn type events have a much higher prevalence of whole body and trunk injuries, while the injury pattern of collisions and ejections type events at these locations is similar to the injuries seen on the street and at industrial areas.

With respect to Figure 4.9, all divisions of the CHAID have a high percentage of internal injury cases. The most significant association, type of LOC event, shows a significant distinction between the diagnoses of overturn events versus the other LOC event types. Fatal overturn events have a higher percentage of anoxia cases, this is due to the mechanism required to produce the conditions necessary for an anoxia event. Nearly every anoxia case occurred when the ATV overturned and pinned the user between the ground and ATV until death. There is a further division within this group, with users operating at home or on the farm having a higher percentage of anoxia cases than other location types. As discussed earlier, ATVs used for occupational purposes may be more prone to overturn events due to terrain characteristics and alterations which effect the center of gravity. In addition, operators using ATV at home or on the farm may be operating alone, in the event of an overturn event, no help may be available to right the ATV before anoxia occurs. Operating in locations where help is readily available may be protective of fatal anoxia cases due to the immediate aid that could be rendered if the overturn event was witnessed. All significant associations in this CHAID were categorized as either agent or environment; no significant factors related to the host were found as related to the injury diagnosis.

5.1.4.Environment Discussion

Location type at time of LOC was a significant association in many of the CHAID decision trees. Statistically significant separation often occurred between operation on a farm versus street environments. According to the results presented in this report, only 12% of fatalities occur in a

farm or agricultural environment. However, when looking at the incident rate of ATV-related fatalities that occur on the farm (.62 per 100,000) versus the overall incident rate (.13 per 100,000), the increased incidence of fatalities on farms becomes apparent. There are several possible explanations as to why the incident rate on farms was higher than the overall rate. Use of ATVs is likely to be a more common occurrence (higher use hours/year) on farms than users who are operating for recreational purposes (Rodgers & Adler, 2001). The higher use rate offers more opportunities for LOC events and thus, a higher incidence of injuries and fatalities (Levenson, 2003). As discussed above, alterations to the weight and balance of the ATV may make it more prone to overturn. This explanation may be the reason why the first significant split of the CHAID for location is type of LOC event (Figure 4.10). There is a significant difference in the type of LOC event based on location type; ejections and collisions have a lower prevalence on the farm than overturn-type events. In addition to the above discussed factors, farms are commonly located in rural areas, away from access to medical care (Balthrop, Nyland, & Roberts, 2009). Difficulty in accessing care may not only delay treatment of serious injuries, but may prevent injured people from seeking treatment all together. Without identification and care, internal injuries which could have been treated may become fatal.

5.2.Application of the Haddon Countermeasures

Haddon's Countermeasures, when applied to ATV use in the United States, can serve as a basis for legislative and design solutions to various areas of safety concern. The following list of general countermeasures was taken from Haddon's 1995 publication, *Energy damage and the 10 countermeasure strategies*.

The first countermeasure, prevent creation of the hazard, is the most severe and abrupt solution to the hazards and mortality rate created by ATV use. This countermeasure, applied to

ATVs, would be eliminating ATVs from the market and passing legislation to ban the use of three- and four-wheeled ATVs. While at first look this solution seems somewhat austere, there is a precedent for similar legislation, as the CPSC began prohibiting the sale of three-wheeled ATVs in the United States in 1998.

Countermeasure number two involves reducing the amount of hazard being created. The application to ATVs would be limiting the number of ATVs available for purchase, limiting the production of ATVs in the United States, as well as placing an embargo on ATV imports.

Countermeasure three is preventing the release of the hazard. Preventing release of the can be limiting the hazard by control measures aimed at high-risk groups and activities. Preventing the hazard from being released could be accomplished by preventing youth and other high-risk groups from operating ATVs, or preventing passengers from riding on ATVs through design changes.

The fourth countermeasure, modifying the rate of hazard release, has already been applied in the United States. In accordance with the 2008 CPSIA, youth and child sized ATVs have been modified to be less powerful and have been governed to operate at a lower top speed (Catenacci, 2009; Fleming, 2010; Rodgers & Adler, 2001; Helmkamp et al., 2009). By modifying the release of the hazard, in this case the velocity of the ATV, the amount of energy transferred from the agent (the ATV) to the host is limited.

Countermeasure number five, separating the hazard by time and space, involves separation of the ATV and/or the user from potential risk factors that contribute to a higher likelihood of morbidity and mortality. To achieve the goal of separation of ATV and user from additional hazards, ATVs should be stored and operated away from areas associated with alcohol and drug use, away from public roadways, and away from areas where children and youth have

unsupervised access to the ATV. The findings of O'Connor, Hanks, and Steinhardt in their analysis of ATV injuries in Queensland present data that supports the potential effectiveness of this countermeasure. Their report found that the majority of injuries occurred during unplanned use in the evening or early morning hours due to convenient access to the ATV (O'Connor, Hanks, & Steinhardt, 2009). Furthermore, the same concept of time and space can be applied to preventative measures, such as storing PPE near the ATV and continuously providing ATV operator training courses in proximity to areas with known ATV users.

Countermeasure six, separating the user from the hazard by a barrier, can be applied through use of engineering controls such as Rollover Protection System (ROPS) to prevent energy transfer to the human body during the occurrence of an overturn LOC event. The barrier of a ROPS may prevent fatalities due to traumatic asphyxia or crushing injuries if the user is able to remain in an area where the ROPS can have the desired effect of preventing the user from being crushed by the stiff areas of the overturned vehicle (Rechnitzer et al., 2013).

Countermeasure seven, modifying the qualities of the hazard, is placing engineering control measures onto the ATV to make them inherently safer. This countermeasure was seen with the transition from three- to four-wheeled ATVs as well as the growing popularity of UTVs and other off-road vehicles with rollover protection. It should be stressed that not all modifications will impact safety in a positive manner. For example, addition of additional mass to the body of the ATV has been shown to change the center of gravity and righting moment, which may make the vehicle more prone to rollover. Modification of the hazard can also be achieved through the use of hands-on training courses. By teaching and practicing how to properly negotiate steep or unstable terrain, users may be able to safely navigate terrain which

would have otherwise caused LOC. Education and practice may also allow the user to recognize when terrain or tasks are unsuitable for ATV use.

The use of PPE can achieve the sixth countermeasure, making what is to be protected more resistant to damage. Use of helmets and other recommended PPE, as well as the absence of alcohol or comorbid conditions will serve to prevent the transfer of potentially deadly energy from the ATV to the rider. Helmets can protect riders' head and neck from impact hazards and protective clothing can protect against injuries such as lacerations, abrasions and burns.

The final two countermeasures aim to prevent the extent damage after injury. Countermeasure number nine, begin to counter the damage done, may be practiced by encouraging ATV users to ride in pairs or groups in order to allow for immediate recognition of injuries and first aid. Riding in groups may also be protective of mortality by anoxia in that groups may be able to help a rider out from under an overturned ATV. Lastly, stabilization and rehabilitation of the damage may be performed by ensuring the availability of EMS resources and access to areas of high ATV use, as well as the availability of emergency treatment and long term rehabilitation services.

While not all countermeasures are feasible, or even practical solutions to reducing the ATV fatality rate, extreme action should be taken to reduce what is becoming a public health problem to both recreational and occupational users. Employers should be aware of the liability and danger of allowing untrained and unprotected users from operating ATVs in the workplace. Training and PPE should be provided in order to prevent workplace exposure to the hazard of operating an ATV as well as loading the ATV with additional equipment and supplies.

5.3. Practical Implications

Current events and increased publicity of the trauma sustained during ATV injuries have brought this, and other recent research into high demand. This report is a representation of the current risks ATVs pose to the user on a national scale. This report should serve as a method of identifying at-risk groups of users in order to create specialized and personalized marketing as well as training solutions. By modeling associated risk factors and categorizing them as pertaining to the host, agent, or environment, it is possible to develop targeted solutions to the root cause of the hazard. Through use of legislation and training, many host-related risk factors can be controlled; use of engineering controls can mitigate risk due to the agent and/or physical environment; and use of targeted marketing strategies and education may be able to limit risk due to the social environment.

The present study is a reminder of the interaction that exists between the host, agent, and environment. No one factor is ultimately responsible for the number of fatal cases seen in this report. These interacting elements each build upon each other, some having more impact than others. Ultimately, categorization and association provides a more thorough understanding of the contributing variables associated with the ATV fatality rate as well as the opportunity for multiple mitigation strategies during the different phases of the LOC event.

5.4. Strengths, Limitations, Future Work

The data utilized in this reported was collected by the CPSC and was designed to fulfill their research and reporting requirements. For this reason, many important data points were missing from the INDP reports. Variables such as alcohol and helmet use were reported irregularly and there was little continuity in information provided in the narrative reports. Variables such as training, experience level, and even time of day, were often never mentioned in the INDP report,

all of which have been determined by prior research to be pertinent factors in probability of LOC. Bias was suspected in the alcohol use statistics due to a large percentage of reports containing no information on alcohol and drug use. Over reporting of alcohol/drug was suspected due to the inability to confirm absence alcohol or drug activity and the reports' lack of recording pertinent negative findings.

The CPSC also relies on news reports and reporting from local medical examiners for notification on the occurrence of an ATV-related fatality. Therefore, if a fatality occurs, not reported by the news, and not reported by other sources, the case, and subsequent CPSC report would not be present in the current database. This reporting bias may have led to the underreporting of cases occurring in rural areas, on farms, and at the home.

In this study, only fatality cases were examined. This was due to the extremely low number of injury-only cases investigated and contained in the reports gathered by the CPSC. For this reason, it was not possible to compare the outcomes of morbidity versus mortality. If all injury cases and fatality cases were reported, it would be possible to organize the study as a case control study, which would allow for the calculation of relative risk.

Accurate data was not able to be obtained on the number of ATVs or ATV users by state or at the national level. The incident rates calculated may be an underestimate due to underreporting of cases, as well as an overestimation of the number of ATVs in use today. In order to obtain accurate data on rates of injury, accurate denominator data must be recorded and obtained.

An accurate and complete analysis of the basic demographics of the nationwide problem of ATV injuries needs to be completed. Understanding the risk factors and the interaction between these factors is essential for designing mitigation strategies as well as building a basis

for legislation. Without standardizing incident reports to contain all essential variables, this analysis cannot be completed. For this reason, a standardized reporting structure should be created in order for pertinent data to be accurately reported across all cases. In order for accurate reporting of incident rates, data on the number of ATVs or ATV users should be obtained from manufacturers and other research institutions.

6. Conclusion

The present study provides nationwide statistics on ATV fatalities, approaching risk factor analysis with regard to the agent-host-environment epidemiological model. This study determined that it was not only host factors that contribute to fatalities, but a combination of all three aspects of the epidemiologic triangle. Using a more comprehensive database of injury and fatality claims, focused research should be performed on the differences that exist between morbidity and mortality.

Use of ATVs is dangerous. While characteristics of speed and instability contribute to the activity's recreational allure, safety during recreational ATV use should not be overlooked. ATV operation should be approached similarly to operation of licensed motorized vehicles where use is regulated and safety precautions are mandatory. Compromises to safety should not be made in the spirit of acceptable risk or in the name of fun. Modification of user behavior is necessary to negatively trend the ATV injury rate and can be attempted using education, training, experience and legislation.

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Appendix I: ATV Regulations by State

From: Specialty Vehicle Institute of America, 2009



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STATE ALL-TERRAIN VEHICLE REQUIREMENTS

May 2009

State	REGISTRATION	TITLE	MV OPERATOR'S LICENSE	MINIMUM AGE	SAFETY EDUCATION CERTIFICATE	EQUIPMENT REQUIREMENTS				PASSENGER PROHIBITION	ON-ROAD USE	CLASSIFIED AS	WEIGHT/WIDTH/DISPLACEMENT LIMITS	OTHER REQUIREMENTS
						LIGHTING	MUFFLER	SPARK ARRESTER	HELMET/EYE PROTECTION					
Alabama				14DS						X	OHV	≤800lbs/≤50" (¶)		
Alaska	*ACEr	*C				*Gr	*Gr	*Cr	*KiE		Q			
Arizona	*A	*		12D		*G	*	*C	*		Zr	≤75"/≤1000cc		
Arkansas	*A	*		14EM, 18En or a	*Ein	*G	*C	*	*KE	*LE	Zr	≤900lbs/≤50"	↘EC	
California	*ACE	*C				*GE	*ICE	*CE			Zr			
Colorado	*A	*		12E, 16Ea & n	*VE	*u	*	*O		*O	Z	≤800lbs/≤50"	↘	
Connecticut	*AC		*F	12D		*G	*C	*			J			
Delaware Dist. of Col.														
Florida		*		16D & aE	*dE	*GE	*IE	*E	*d	*LE	X	OHV/ATV	≤900lbs/≤50"	
Georgia													<1000lbs/≤50"+	
Hawaii														
Idaho	*B	*									Q	ATV	≤900lbs/≤50"	↔±s61"
Illinois	*										Zr	ATV/OHV	≤900lbs/≤50"	↘
Indiana	*BC	*Y	*F	14D		*G	*				Zr	ORV		↘
Iowa	*BE	*	*F	12DE, 18aE	*IE	*G	*			*L	Z (re)	ATV	<1000lbs/<1000cc	
Kansas		*									g	ATV	≤1500lbs/≤50"	∅≤14"
Kentucky		*	*F	12R, 16u & D		*F	*		*K(d, Er)		Zr	ATV		
Louisiana	*Ar	*r									X	ORV		
Maine	*AC			10, 16D & a	*c	*u	*C	*	*Ki		Z	ATV		
Maryland	*BS	*PS		12S		*GS	*IS	*	*S		Z	ORV		
Massachusetts	*B	*		10, 12S, 14D, 16½F					*K		Z	RV		
Michigan	*B	*	*FID & a	12C, 16t & D & a (W)	*IC	*G	*C	*	*K	*L	Z	ORV/ATV	≥500cc-≤500cc	↘
Minnesota	*B	*		10E, 12uE, 16Ea & D	*rY	*FG	*IC	*	*KE	*W	Q	ATV	≤900lbs/≤600cc+	
Mississippi		*												
Missouri	*A	*		16D		*C	*C	*C	*Ki	*L, r	X	ATV	≤1000lbs/≤50"	
Montana	*A	*					I	*			Q	OHV		
Nebraska		*Y				*F & G	*	*C	*	*L	X (re)	ATV	≤900lbs/≤50"	
Nevada							*	*	*		Q	OHV		
New Hampshire	*Bk	*Fa		14D & a	*q	*u	*C	*S	*i	*i	Z	ORV/ATV	≤1000lbs/≤50"	∅≤10
New Jersey	*ACE			x, 14E, 16uE	*ICE	*C	*	*	*K		Z	ATV	≤600cc	
New Mexico	*AE	*E		6, 10D & b, 18D(W)E	*IE	*GE	*E	*E	*IE	*IE	Zr	ATV/OHV	<1000lbs/≤50"	↘
New York	*AC			10D, 16D or a	*CD	*GC	*IE	*	*K	*L	Z	ATV	<1000lbs/≤70"	
North Carolina	*ACE	*a	*F	8, 12R, 16u & D, p, h	*S	*G	*	*	*F	*L	Z	ATV		
North Dakota	*Ar	*a		12, 16D or a	*d	*	*S	*	*K	*L	X	Class II OHV	<50"	
Ohio	*Ar	*E		16D, 12S		*G	*I	*	*S	*L, S	X	APV		
Oklahoma	*AY	*Y	*F		*SG				*KE	*LE	X	ATV	≤800lbs/≤48"	
Oregon	*BS	*		16n & aE, ‡	*dE	*G	*I	*S	*KE		Zr	ATV	≤800lbs/≤50"	↘
Pennsylvania	*B	*		8E, 10RE, 16a	*o	*G	*I	*S	*K		Z	ATV	≤1000lbs/≤50"+	↘
Rhode Island	*B	*T		12S, 16SD & F, w	*d or z	*F & G	*C		*K		Z	RV/ATV		↘
South Carolina		*												
South Dakota		*												
Tennessee		*									N	ATV/ORV		
Texas	*BS	*		14D		*E	*E	*EC	*Ki	*E	Z	OHV/OHV		
Texas	*AE	*aE		8E, 16a & FD	*rE	*GE	*G	*	*E	*L	Zr	ATV	≤800lbs/≤50"	∅=12", ∅≤10
Utah					*rE				*Ki		Q	ATV/OHV		
Vermont	*AE	*		12D, 16FD, 18a	*i	*C	*C	*C	*K	*L	Z	ATV	<1700lbs/≤60"	∅=10
Virginia		*YU		12R, 16u					*K		Zr	ATV		
Washington	*Ar	*		13F & VD		*G	*I	*	*Kr		Zr	NHV/ORV		
West Virginia		*		18a	*i	*G	*	*	*Ki	*HL	Q	ATV	≤800lbs/≤52"	
Wisconsin	*BC	*		12r & D(W)	*y	*F & G	*I	*	*Kir		Zr	ATV	<900lbs/≤48"	∅≤12", ∅≤6
Wyoming	*BS	*							*		X	ORV		

- * Required by law or regulation
- A By motor vehicle registration agency
- B By recreation management agency
- C Except in authorized events
- D Unless supervised
- E Applies only on public lands
- F To cross highway &/or for allowed hwy. use
- G For night operation only
- H More than 1 passenger prohibited & passenger under age 18 unless operator has specified driver's license or is at least age 18 prohibited
- I Decibel limit specified
- J Prohibited
- K Approved helmet
- L Except if designed to carry passenger
- M Unless supervised by parent or his designee and either has safety certificate or is supervised by adult with certificate
- N Prohibited except to cross highway & by registered ATVs with 4 or more wheels & 200 cc or more
- O ATV definition specifies single rider
- P Must have license or learner's permit, or be accompanied by licensee or by parent
- Q Allowed as specified in law
- R For ATV over 70cc
- S Applies only on specified public lands
- T For ages 16-18 to cross highway

- U For ATV over 50cc
- V On specified lands
- W Additional provisions apply; law too complex to summarize completely
- X Prohibited with specified exceptions
- Y For ATVs purchased after date specified in law
- Z Prohibited except to cross highway
- a Unless safety certificate is possessed
- b Unless on age-appropriate sized ATV
- c For ages 10-15
- d Under age 16
- e During daylight hours only
- f If issued to persons age 12-15, not valid for ATVs > 90cc unless training course completed on ATV > 90cc & able to reach handbars & footpegs
- g Prohibited on specified highways
- h cc restrictions not applicable to persons born by 8/15/87 with parent or guardian who owned ATV prior to 8/15/05
- i For persons under age 18
- j For persons age 16 & over
- k Not required in certain cases for ATVs ≤ 95cc
- m Unless motor vehicle operator's license possessed
- n Unless supervised by adult with safety certificate
- o For ages 8-15

- p Sale for use by person under age 8 prohibited; sales restrictions based on age/cc size
 - q Under age 14
 - r Except if engaged in agricultural &/or other specified activities
 - s For persons born on/after 1/1/90
 - t For 3-wheel ATVs
 - u For ATVs over 90cc
 - v For all ages; under age 18 must complete safety course
 - w Sale to under age 16 prohibited
 - x Sale of ATV over 90cc for use under age 16 prohibited
 - y For persons born after date specified in law
 - z For 1st-time ATV buyers
 - # Separate limits for Class II ATVs
 - ⊠ Provisions exclude ATVs engaged in farming, hunting or trapping
 - ‡ Except on ocean beach areas open to ATVs
 - † Unless meeting rider-fit requirements
 - ¶ Applies only to ATVs operated on highways as specified
- OTHER REQUIREMENTS**
- ∅ Wheel/rim diameter
 - ⊙ Tire pressure (psi)
 - ↔ Wheel base

↘ Braking capability
↗ Reflectors/reflectorized material

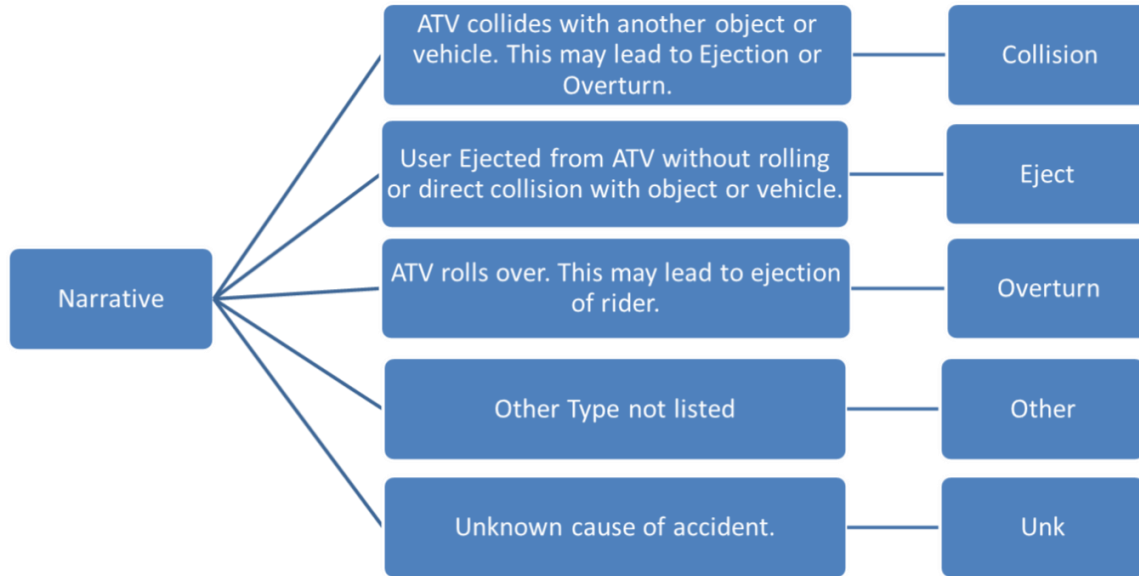
CLASSIFICATION ABBREVIATIONS

APV	-	All-purpose vehicle
ATV	-	All-terrain vehicle
NHV	-	Non-highway vehicle
OHV	-	Off-highway vehicle
OHMV	-	Off-highway motor vehicle
OHRV	-	Off-highway recreation vehicle
ORV	-	Off-road vehicle
ORRV	-	Off-road recreational vehicle
RV	-	Recreation vehicle

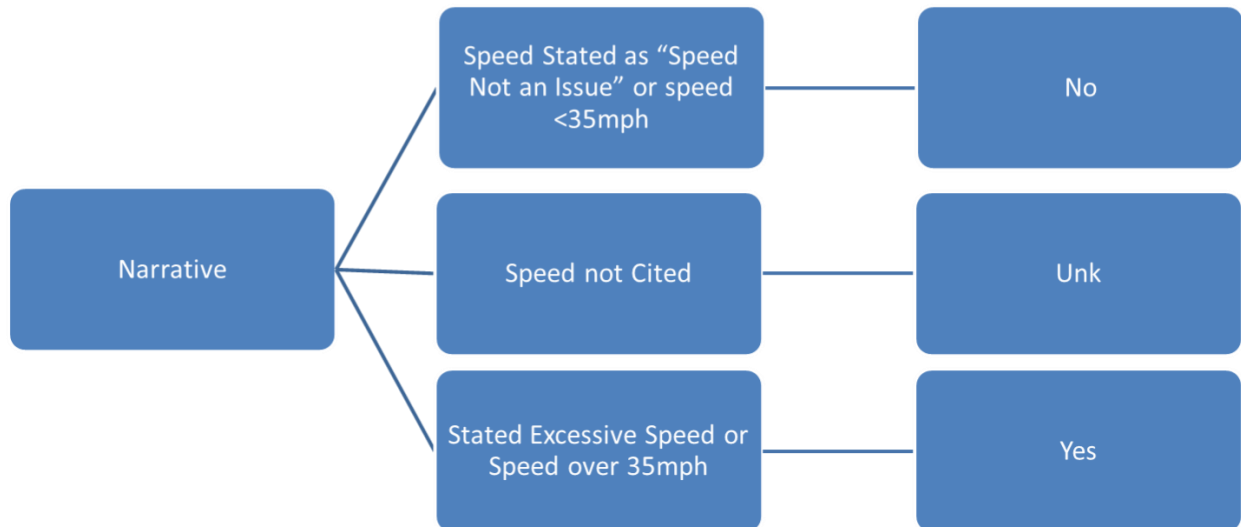
This chart is compiled by SVIA's Government Relations Office. Please contact SVIA for additional information concerning ATVs. Although this chart represents information from the most authoritative sources available, SVIA is not responsible for accuracy or completeness. Many of the provisions summarized herein have exceptions and may require further explanation. It is necessary to refer to the actual laws and regulations for specific details.

Appendix II: Case definition decision trees

Type of Accident

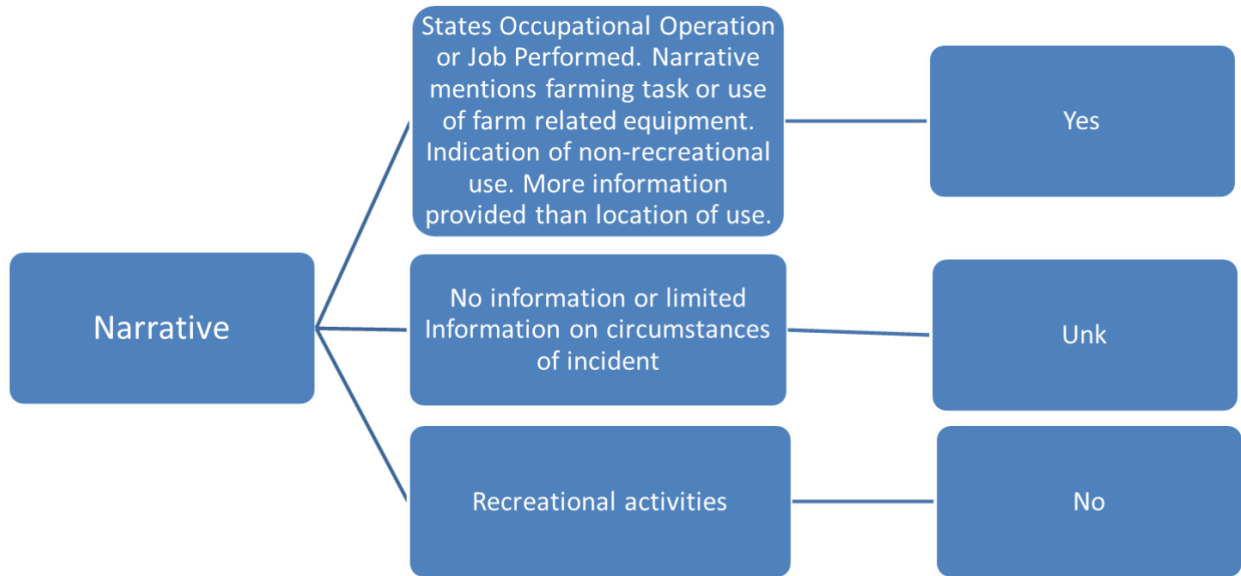


Excessive Speed

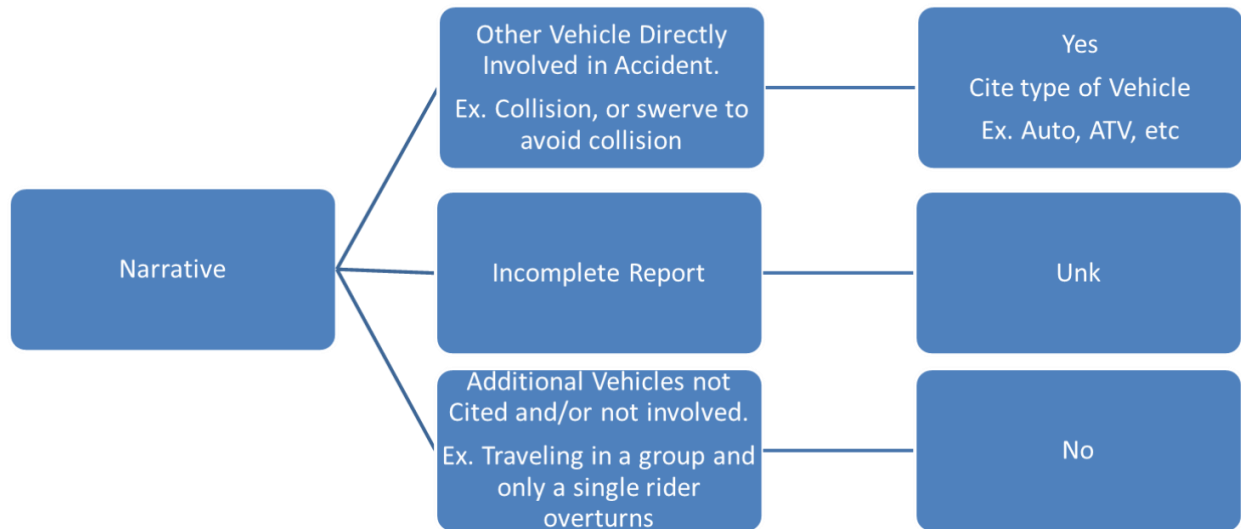


Appendix II: Case definition decision trees (Continued)

Occupational?



Other Vehicle Involved?



Appendix II: Case definition decision trees (Continued)

Mechanical or Design Failure

