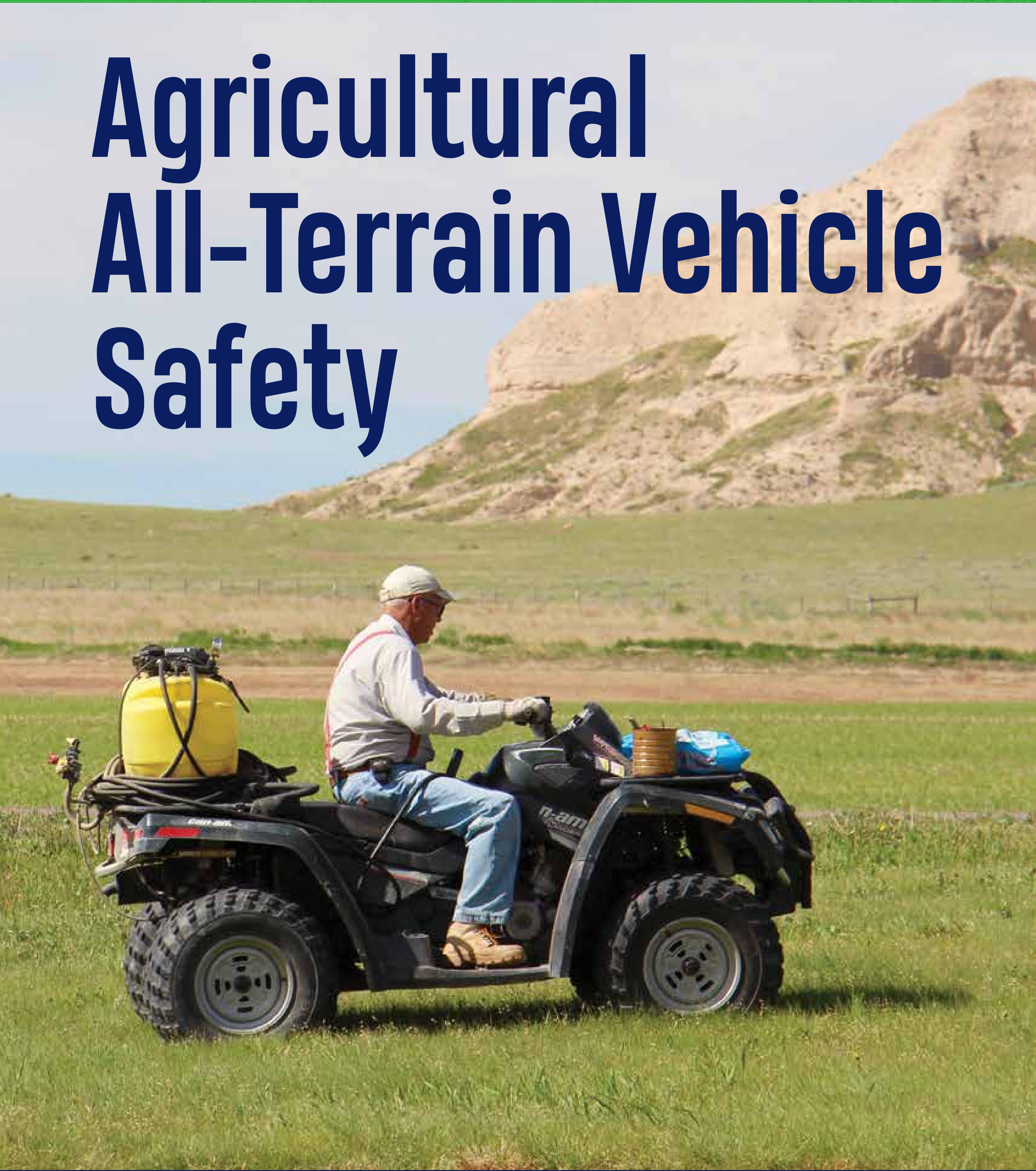
Agricultural All-Terrain Vehicle Safety



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1. Introduction

"All-terrain vehicle (ATVs) are commonly used to inspect crops and livestock; to fertilize and apply chemicals; to inspect and repair irrigation systems and fence lines; to supervise field crews; to herd livestock; to mark timber; to mow grass, to move dirt and to transport things from here to there and back again."
- (Murphy & Harshman, 2017)

The American National Standards Institute (ANSI) defines an ATV as a vehicle that travels on low-pressure tires, with a seat that is straddled by the operator and with handlebars for steering control (Consumer Product Safety Commission, 2006). The Consumer Product Safety Commission (CPSC) reported 14,653 ATV-related fatalities occurring between 1982 and 2016, and in 2016, CPSC estimated 101,200 ATV-related, emergency department-treated injuries in the United States. CPSC in 1985, declared that ATVs are an "imminently hazardous consumer product" (Consumer Product Safety Commission, 2006). CPSC commenced rulemaking to address hazards associated with ATVs, and in 1988, a 10-year consent decree included the prohibition of the sale of three-wheeled ATVs, which were known to be more unstable regarding rollovers than four-wheeled ATVs (David, 1998). The Consumer Product Safety Commission Improvement Act of 2008 placed a permanent ban on three—wheeled ATVs pending rulemaking by the CPSC (US Congress, 2008).

Most injuries related to ATV collisions and rollovers occur in rural areas that includes off-road and on-road crashes. ATV use is prevalent on farms, but the use of these vehicles for agricultural tasks has been little studied (Jennissen et al., 2017). One study in Iowa found that while 39% of ATV crashes occurred in isolated rural and small rural areas, but 62% of these crashes resulted in fatalities(Qin, Jennissen, Wadman, & Denning, 2017). Of an estimated 1.1 million youths living on farms, 36% had operated an ATV in 2001. An estimated 2,246 nonfatal ATV-related injuries occurred to youths younger than 20 years on US farms. Most ATV injuries were the result of recreational activities (970, 58%) (Goldcamp, Myers, Hendricks, Layne, & Helmkamp, 2006).

Few studies have been conducted in the United States regarding farm-related ATV injuries, on-farm injuries may include non-work-related activities, and children are part of the at-risk population. Moreover, little is known about the risk factors and ATV-related injuries in the agriculture industry.

This purpose of this document is to describe what is known about ATV-related injuries on farms, recommend approaches for preventing these injuries, and suggest directions for future research. The epidemiology of these injuries is framed by the qualitative two-dimensional Haddon matrix (Haddon, 1980), and a third dimension that addresses prevention (Runyan, 2015), using the hierarchy of controls that sets up a precedence order for the effectiveness of injury prevention and control. The National Safety Council 3-E's—Engineering, Education, and Enforcement—are mapped against these constructions and is used for safety promotion. Table 1 shows the Haddon matrix.

active controls where conversely, protection depends upon the worker's actions. Wogalter (2006) expanded this hierarchy to three tiers in order of effectiveness: 1—eliminate hazards, 2—guard against the hazard when it is not possible to eliminate hazards, and last, 3—warn against the hazard if other controls are inadequate.

Standards-setting organizations have used a broader scope for the hierarchy of controls as

Table 1. Haddon matrix of potential risk factors related to ATV crashes and rider injuries on farms

Influence factors		***Pre-crash***	***Crash***	***Post-Crash***
ATV		Stability, protective devices, load, crashworthiness, implements	Collision, rollover, rear or frontal flip, speed	Repair, disposal
Environment	Physical	Slopes, trip hazards (obstructions), load, road transport		
	Social	Rules, guidelines. Recommendations	Local laws	Compensation, cost, EMT response, trauma care
ATV rider		Activity, training, age, multiple riders, helmet use, other personal protective equipment	Injured, injury mechanisms (crushed, asphyxiated, fall injury)	Injury severity, body parts injured

The Haddon matrix shows the risk factors based on a public heath model of agent (ATV), environment (physical and social), and host (ATV rider) through condition before and after a crash, during the crash, and after the crash. Table 1 includes ATV safety factors, environmental conditions, social situations such as incident response, personal factors such as helmet use, injury circumstances, and injury severity.

Regarding the hierarchy of controls, (Haddon, 1980) established the best method as passive controls in which protection does not depend upon the worker's actions followed by

a means of determining how to implement feasible and effective control solutions as shown in Figure 1 (National Institute for Occupational Safety and Health, 2018). Following the hierarchy of controls can lead to inherently safer systems substantially reduce the risk injury. However, acceptance of protective technology may be hindered by perceived (e.g., risk normalization) and real (e.g., cost) barriers, and identifying and using motivators (e.g., family or worker protection) would be in order through social marketing techniques (Myers, Kelsey, Tinc, Sorensen, & Jenkins, 2018).

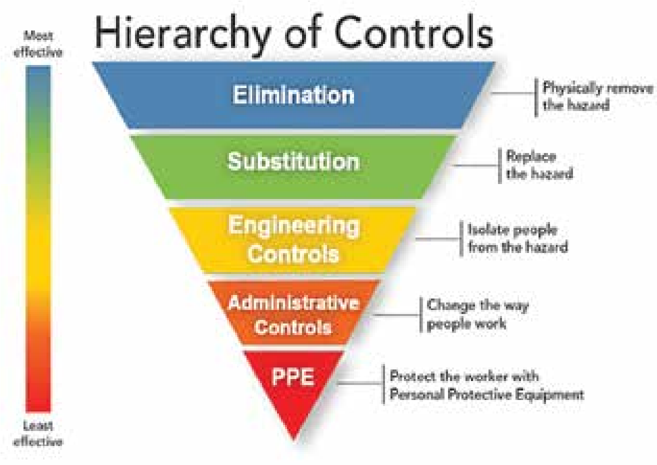


Figure 1. Hierarchy of Control

The sections that follow address definitions, injury risk factors and mechanisms, experimental tests regarding ATV static and dynamic stability and crashworthy tests, and a range of potential interventions to control or prevent crash-related injuries. The paper concludes with a discussion of future research, actions that can be taken, and recommendations for preventive actions.

2. Definitions

A four-wheel ATV can be defined as "a motorized off-highway vehicle designed to travel on four low pressure or no-pneumatic tires, having a seat designated to be straddled by the operator and handlebars for steering control" (ANSI/SVIA, 2017).

For this document, Adult-size Type 1 ATV classifications can include both Utility or Agricultural ATVs (category G), and Sport ATVs (category S) (ANSI/SVIA, 2017).

Utility or Agricultural ATVs tend to have:

1) Front and rear racks for carrying loads or mounting equipment
2) Trailer hitch
3) 4-wheel drive
4) Automatic transmission
5) Winch
6) A 12-volt power plug

Sport ATVs tend to have:

1) No or small load racks
2) No trailer hitches
3) Rear wheel drive (some)
4) Manual transmissions (some)
5) No winch
6) No 12-volt power plug

2.1 Recreational vs. agricultural ATV incidents

"Although ATVs are very popular in rural areas for both recreation and work purposes, the epidemiology of agricultural ATV use remains largely unknown."—(Jennissen et al., 2017).

The agricultural ATV is likely a utility ATV used in agriculture, but it may also be used for recreation. ATVs have two crucial design differences. One design is for sport as shown in Figure 2, and an example of a utility vehicle is shown in Figure 3. Note that the sport design is for a single rider with no consideration for work-related attachments, whereas utility ATVs have the means for carrying cargo or mounting equipment such as sprayers and has a hitch that can be used to pull implements. Utility ATVs are also recreational vehicles but have cargo racks and can be fitted with attachments, including trailers, and have utility purposes such as doing farm chores. Utility ATVs have cargo racks and can be fitted with attachments, including trailers, and have utility purposes such as doing chores and for farming (Murphy & Harshman, 2017).

Figure 2. An example of a sport ATV

While sport ATVs lack value for farm work except for personal transport, utility ATVs are useful for a variety of agricultural and non-agricultural (e/g/, recreational hunting) tasks. One way for identifying agricultural verses non-agricultural ATV use is to focus on occupational pursuits. As an example, in the United States, a study in Montana for the years 2007-2012 found that 59% of ATV-related workers' compensation cases occurred in agriculture (Lagerstrom, Gilkey, Elenbaas, & Rosecrance, 2015). However, workers' compensation rarely includes the farm owner and their family.

Figure 3. An example of a utility ATV

The US Department of Transportation's Fatality Analysis and Reporting System (FARS) indicates that the majority of ATV-related fatalities on roads and highways occur in rural areas (Williams, Oesch, McCartt, Teoh, & Sims, 2014). A state-based trauma database regarding off-road ATV-related injuries, which occurs off-road, also indicated a majority of cases occurred in rural areas (Qin et al., 2017). A sample of more than 650 agricultural students across Arkansas found that 60% of the subjects rode ATVs and were at a higher risk of injury than non-farm youth (Jones & Bleeker, 2005). Opportunity sampling at events attended by farmers and ranchers offers another approach for examining the epidemiology of ATV-related injures (Jennissen et al., 2017).

A NIOSH 2001 Childhood Agricultural Injury Survey included information regarding ATV's. They estimated that 36% of 1.1 million youths on farms had operated an ATV, of whom 2,246

≤20 years of age experienced a nonfatal injury. Most (74%) were household members, and most injuries (58%) were associated with recreational activity (Goldcamp et al., 2006).

3. Risk factors

The risk factors include human factors, vehicle factors, activity environmental and roadway conditions which will be evaluated in this section. This risk factors will be reviewed in more details in the following section.

3.1 Human characteristics

a) **Gender, age,:** Studies showed that being male and young increased the risk of injury (Rodgers & Adler, 2001; Shulruf & Balemi, 2010). In ATV related roadway incidents, most of the drivers involved in roadway incidents were males (Denning, Harland, Ellis, & Jennissen, 2013; Williams et al., 2014).

b) **Presence of passenger, passenger's age, seating position of passenger**: Unless ATV specifically designed for passengers, presence of passenger increases the risk of incidents since having a passenger has a negative effect on vehicle control and stability (Campbell et al., 2010; Jennissen, Harland, Wetjen, & Denning, 2016; Williams et al., 2014). Presence of passenger also can be considered as a social environment factor including behaviors associated with group riding (Fleming, 2010).

c) **Contributing operator actions**: Previous studies reported low helmet usage and alcohol and drug involvement in ATV crashes (Denning et al., 2013; Fleming, 2010; Hall, Bixler, Helmkamp, Kraner, & Kaplan, 2009; Lagerstrom, Magzamen, Stallones, Gilkey, & Rosecrance, 2016; Williams et al., 2014).The most frequently cited operator contributing factor for the ATV operators was reported as 'going too fast for conditions' or 'exceeding the speed limit' (Gorucu, Murphy, & Kassab, 2017; Williams et al., 2014). Other operators contributing factors are being inexperienced, affected by physical condition, failing to yield the right of way, driving not in proper lane and not obeying traffic signals (Gorucu et al., 2017; Williams et al., 2014).

d) **Operator's experience**, **training course, safety knowledge:** Studies reported that estimated risk of injury declines with driving experience and training (Goldcamp et al., 2006; O'connor, Hanks, & Steinhardt, 2009; Rodgers & Adler, 2001). Using personal protective equipment like Helmets and appropriate riding gear (e.g. boots, leather gloves, long sleeve shirt, and long pants) contributes to decreases in the severity of injury (Fleming, 2010; Mangus, Simons, Jacobson, Streib, & Gomez, 2004; Myers, Cole, & Mazur, 2009).

3.2 Vehicle properties

a) **ATV make and model:** Studies reported that estimated risk of injury for three-wheel ATVs were higher than four-wheel ATVs and increasing engine size was associated with higher injury risk (Rodgers & Adler, 2001). Engineering findings show that three-wheel ATVs are less stable than four-wheel ATVs (Deppa, 1986).

b) **Safety devices (headlights, taillights, and roll bar,):** All lights must be lighted during the hours of darkness, while operating on or along a roadway, while crossing a roadway (CPSC, 2019). Studies shows that ATV roll bar reduce risk for crush injury (Franklin, Knight, & Lower, 2014; Lower & Trotter, 2014; Myers, 2016a). Researchers studying crash protection devices' (roll bar) effectiveness have estimated a 70% reduction in ATV-related fatalities in Australia and New Zealand.

c) **Matching ATV engine size and age of the operator:** Studies suggest youth <16 years of age do not have the physical strength, cognitive maturity, and judgment to reliably operate adult-size ATVs safely. Death and injury data also demonstrate that nearly all pediatric deaths and injuries occur on adult-size ATVs (Denning & Jennissen, 2018). Recommended engine size by operator's age are given in Table 2 (CPSC, 2006).

Table 2. Age of operator and the ATV engine size (CPSC, 2006).

Age of Operator	*ATV Engine Size*
Under age 6	not recommended
Age 6-11	under 70 cc
Age 12-15	70-90 cc
16 years & older	over 90 cc

3.3 Operating activity

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). ATV death rate in agriculture/forestry/fishing/hunting industry was reported to be 100 times greater than other industries (Helmkamp, Marsh, & Aitken, 2011). A study of ATV-related fatalities in Australia between 2000 to 2013 found farmworkers are more likely than recreational riders to become pinned under an ATV and die of asphyxia (McIntosh, Patton, Rechnitzer, & Grzebieta, 2016).

3.4 Environmental conditions

Paved surfaces use: ATVs are not intended for on-road use and have design features that can increase risk when operated on paved surfaces (General Accounting Office, 2010). Riding on public roads/paved roads increases the risk for fatalities (Denning & Jennissen, 2016; Neves, Brazile, & Gilkey, 2018; Shulruf & Balemi, 2010; Williams et al., 2014). ATVs have low-pressure tires that are intended to increase grip on uneven and low friction surfaces. Riding on paved surfaces results in far greater tire to road friction and/or adhesion resulting in vehicle lateral load shifting and tendency to rollover, especially when turning at higher speeds (Neves et al., 2018).

In a study by Gorucu et al. (2017), only very small portions of the crashes were caused by the environmental and roadway conditions in roadway ATV related crashes in Pennsylvania. Environmental and roadway factors can be lighting condition (daylight, dark, etc.) and weather, the slope of the terrain, terrain surface condition (soil, gravel roads, off-road trail), environment descriptors (i.e. rural highway, farm, wooded area, personal property, forest).

4. Injuries mechanisms

Mechanism of injury include ejection from the ATV; backward roll-overs, crashes on sloped terrain, and collisions with motorized vehicles (Jennissen et al., 2016). Injuries associated included head or brain trauma, bone fractures, renal injury, spleen and liver lacerations, and fatal traumatic asphyxiation (Bowman & Aitken, 2010; Denning et al., 2013; Helmkamp, Ramsey, Haas, & Holmes, 2008; Kelleher et al., 2005). Research results show high morbidity and mortality among youth involved in ATV crashes. Hospitalization of individuals involved in an ATV incident is more likely among male and youth riders (Denning & Jennissen, 2018). The length of hospitalization varied from between four and six days. Youth involved in a ATV incident who did not wear a helmet experienced more severe injury and longer hospital stays (Brown, Koepplinger, Mehlman, Gittelman, & Garcia, 2002; Gittelman, Pomerantz, Groner, & Smith, 2006). Brain injuries were significantly associated with disability requiring rehabilitative care with the potential for transfer to a rehabilitation facility (Denning & Jennissen, 2018). United States data from 2000-2004 documented that rural hospital emergency rooms treated 23% of the ATV injury cases while urban teaching hospitals treated 47% (Helmkamp, Furbee, Coben, & Tadros, 2008).

5. Possible solutions

The possible solutions based on hierarchy of control are discussed in this section (Figure 1) which includes elimination, substitution, engineering controls, administrative controls and personal protective equipment.

5.1 Elimination or substitution

At the top of the hierarchy of controls, the first priority is to eliminate the hazard and failing this, to find substitutes for the hazardous technology. Elimination was used to ban the use of three-wheeled ATVs as discussed earlier. Like tractors, banning the four-wheeled ATV is not an option because of its broad acceptance as a useful vehicle on farms (Hicks et al., 2018).

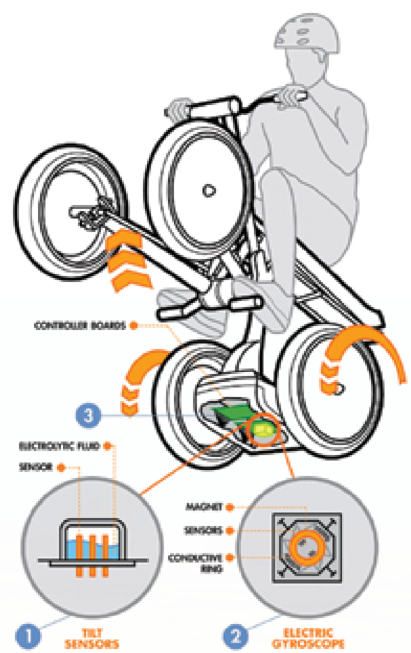


Figure 4a, Segway Centaur Design (photo credit: www.popsci.com)

However, technical advances by Segway may provide a solution to the ATV rollover problem (Everett, 2004). The Segway Centaur is conceived as a self-balancing human transporter (Figures 4a and 4b), but advances could lead its use for utility functions.

Figure 4b. Segway Centaur
(photo credit: www.seriouswheels.com)

Recreational off-highway vehicles (ROVs, also known as side-by-side vehicles) are different from ATVs by the presence of a steering wheel instead of a handle bar for steering, bench or bucket seats for the driver and passenger(s) instead of straddle seating, and foot controls for throttle and braking instead of levers located on the handle bar. In addition, ROVs have a rollover protective system ROPS, seatbelts, and a maximum speed greater than 30 mph. Typically, passenger handholds are present for the passenger to grasp in the event of a rollover and prevent grasping the pillar and resulting hand injuries if in a rollover (Figure 5). Since the ROV has a ROPS and seatbelts, it is considered to be safer as a substitute for the ATV. Research in Australia compared ATVs to ROVs, which identified superior static stability, dynamic handling, minimal steering disturbance when traversing a bump, and rollover crashworthiness of ROVs (Hicks et al., 2016).

Figure 5. Recreational Off-highway Vehicle
(note the passenger handhold).
(photo credit: www.consumerfed.org)

5.2 Engineering control

Different engineering control methods including evaluate static stability of ATV, improving vehicle safety through crash testing and stability ratings, use of automatic system to notify first responders of a crash, and testing and applying operator protection device on ATVs are discussed in this section.

5.2.1 ATV Static Stability Tests

The static stability angle is the angle at which the ATV initiates rollover in a static condition. Static stability angles are useful for defining the relative stability of the ATV during operation to avoid rollovers. Several approaches can be used to determine the static lateral (side) and longitudinal (rear) stability angles of ATVs. Most approaches involve either (1) the use of a tilt table to directly measure the stability angle, tilting the vehicle until rollover is initiated, or (2) determining the center of gravity and calculating the static stability angles based on vehicle dimensions (wheelbase and tread width). Accurate measurement of the vertical height of the center of gravity is critical for calculating the vehicle static stability angles. A common technique for determining the vertical height of the center of gravity is the axle lift method, in which an axle is lifted and the weight shift between the front and rear axles is used to calculate the height of the center of gravity. Liljedahl, Turnquist, Smith, and Hoki (1989) presented equations for applying the axle lift method to calculate the vertical height of the center of gravity.

The ISO 16251-2 standard provides a numerical approach to applying the axle lift method to calculate the location of the center of gravity and determine the static overturning angles for self-propelled agricultural machinery (ISO, 2015). The standard also describes the need to consider the weight shift created by moving fluids inside the vehicle. Khorsandi, Ayers, Freeland, and Wang (2018) investigated the influence of fluid shift on the calculated center of gravity. They found that, for a tractor at high lift heights, the normally small amount of liquid (fuel, oil, coolant, etc.) does not substantially influence the center of gravity and static stability angle calculations.

The ANSI/SVIA 1-2017 standard describes the measurement of a "balancing angle" for ATVs (ANSI/SVIA, 2017). The calculated pitch stability coefficient (K_p) must be greater than 1.0. Coefficient K_p is different from the tilt ratio (tangent of tilt angle) determined using the tilt table stability test (Grzebieta, Rechnitzer, & Simmons, 2015b). One possible reason is that the "balancing angle" appears to balance the ATV center of gravity over the rear axle, which may be free to rotate. If the rear axle is not free to rotate, then the vehicle will balance over the rear tire-terrain contact point. The longitudinal static stability angle is higher if the rear axle is free to rotate. Stability requirements in the lateral direction are not discussed in ANSI/SVIA 1-2017.

Ayers, Conger, Comer, and Troutt (2018) determined the center of gravity locations and the static lateral and longitudinal stability angles for four ATVs in both loaded and unloaded (without operator) conditions. The unloaded static lateral stability angles ranged from 36.9° to 41.3°. The unloaded static longitudinal stability angles ranged from 45.3° to 51.6°. Loading the ATVs decreased the average static lateral and longitudinal stability angles by 17.2% and 20.9%, respectively. Compared to the off-road utility vehicles (ORUVs), lawn tractors, zero turn radius mowers and agricultural tractors tested, the ATV's had the lowest static lateral stability angles.

Grzebieta, Rechnitzer, and Simmons (2015b) used tilt table stability tests to evaluate the static stability angles of eight agricultural ATVs and five ORUVs or "side by sides". With an operator, the lateral stability angle ranged from 24.5° to 30.8° for the ATVs and from 32.9° to 43.8° for the ORUVs. When the vehicles were loaded (front and rear), the lateral and longitudinal static stability angles for the ATVs decreased by about 2.0° and 3.5°, respectively. With an operator, the longitudinal (rear) stability angles ranged from 37.9° to 43.6° for the ATVs and from 46.0° to 56.2° for the ORUVs. The lowest recorded stability angle was 22.2° in the lateral direction for a fully loaded agricultural ATV. (Heydinger et al., 2016) evaluated the lateral and longitudinal stability angles for 12 ATVs. They found that the stability angles calculated from the track width and center of gravity were higher (by 5.0° to 8.0°) than those measured with the tilt table. They concluded that the vehicle suspension and tire flexibility caused the tilt table stability angle to be lower. However, they did not specifically state if the tread width was a center-to-center or outside-to-outside measurement. The later measurement would produce a higher stability angle (more stable). The differences between the left and right lateral tilt stability angles were small and mostly within 0.5°. In addition, adding loads to the ATVs decreased both the lateral and longitudinal stability angles by 4.0° to 7.0°.

5.2.2 Improving vehicle safety through crash testing and stability ratings

The New Cars Assessment Programs (NCAP) throughout the world have shown how crash testing can provide consumers with important information about the relative safety of motor vehicles to assist them in making decisions about what vehicles to purchase. In addition, vehicle manufacturers have featured their performance in the NCAP tests as a way of promoting the safety of their vehicles. Having a similar program for ATVs and side-by-side ATVs will encourage manufacturers to make safety improvements in those vehicles.

The National Highway Traffic Safety Administration (NHTSA) is the federal agency within the US Department of Transportation that regulates motor vehicle and highway safety. In the case of vehicles designed to be used on public roads, NHTSA sets Federal Motor Vehicle Safety Standards that every vehicle sold in the U.S. must meet. The standards cover three major areas. There are standards intended to reduce the frequency of crashes by setting performance requirement for, among other things, brakes, tires, and headlights. A second set of standard set performance requirement intended to protect an occupant in the event of a crash by setting performance requirements for, among things, seat belts, head restraints, and airbags. The third set of standards are intended to reduce post crashes injures by requiring fuel systems and batter in electric vehicle not to rupture and spread gasoline or battery fluid after the crash (National Highway Traffic Safety Administration, 2019).

The occupant crash protection standards that use crash testing that are based on a specified test speed. For example, FMVSS 208, Occupant Crash Protection, uses a 30-mph frontal barrier impact, which simulates one vehicle of the same weight striking head-on with another vehicle of the same weight. To encourage manufacturers to improve the safety of their vehicles beyond the minimum requirement of the federal standards, NHTSA created the New Car Assessment Program (NCAP) in 1978 and released the first test result in 1979. NHTSA created a rating system which ranges from 1 to 5 stars, with 1 star being the lowest and 5 stars the highest. Because of NCAP, consumers now demand safety features and performance that goes beyond the minimum federal requirement. More and more vehicles are now achieving four and five stars and manufacturer feature the star rating in their advertisements.

Global NCAP is an organization that promotes the development of new car assessment program throughout the world (Global New Car Assessment Programme, 2019) At present, there are NCAPs in Australia & New Zealand-(Australasian New Car Assessment Program, 2019), China (China New Car Assessment Program, 2019), Europe (Europe New Car Assessment Program, 2019), Japan (Japan New Car Assessment Program, 2019), Korea (Korean New Car Assessment Program, 2019), Latin America (Latin America New Car Assessment Program, 2019) and South Asia (South Asian New Car Assessment Program, 2019).

The Insurance Institute for Highway Safety (IIHS) is an independent, nonprofit scientific and educational organization dedicated to reducing the losses – deaths, injury, and property damage – from motor vehicle crashes. It is funded by the motor vehicle insurance industry. In 1995, it released the first results for its New Car Assessment Program (Insurance Institute for Highway Safety, 2019). The purpose of the program was to create crash tests not used in the NHTSA NCAP to put additional pressure on vehicle manufacturers to improve the safety of their vehicles. For example, the IIHS frontal crash uses a 40-mph test speed rather than the 35-mph test speed used in NHTSA NCAP. In addition, it uses a test that simulates 40 percent of one vehicle striking 40 percent of the front of another vehicle, rather than simulated a head-on crash as in NHTSA NCAP.

Both NHTSA and IIHS now include information crash prevention technologies, such a blind spot detection, lane departure warning and autonomous emergency braking, which is designed to detect an impending crash and automatically brake the vehicle to prevent the crash or to reduce the severity of the crash. The purpose of the information is to educate consumers about how the systems work and why they are important.

In 2011, the New South Wales Workcover Authority, similar to a state Occupational Safety and Health Administration in the US, helped funded a research program at the University of New South Wales to create an Australian Terrain Vehicle Assessment Program to rate the relative safety of ATVs and side-by-side ATVs. UNSW created a series of static tests to evaluate the vehicles. The tests included a test to measure the stability of the vehicle in a lateral roll, forward pitch and rear pitch test. It also includes dynamic handling tests and rollover crashworthiness tests (Grzebieta, Rechnitzer, Simmons, Hicks, et al., 2015).

The Australian Consumer and Competition Commission, which is the equivalent of the U.S. Consumer Product Safety Commission, issued a white paper on ATV safety in November 2017 that proposed several countermeasures to improve the safety of ATVs, including the creation of a program to rate the relative safety of ATVs and side-by-side ATVs (Australian Competition & Consumer Commission, 2017a) The ACC is now considering whether to implement a safety rating programs of ATVs and side-by-side ATVs.

5.2.3 Operator Protection Device

An Operator Protection Device (OPD) is a passive control that is independent of the action of the potential victim of injury. OPDs protect the operator in rollover accident by providing a Crush Protection Zone (CPZ) under the vehicle in the event of rollover accident. Such systems may have protective benefits in some rollover accidents, but OPDs will not prevent the rollover accidents from occurring. OPDs may not be effective in all rollover accidents which involves an active separation and hitting the hard parts of the ATV (Grzebieta & Achilles, 2007). In this document, the OPD refers to both the Crush Protection Device (CPD) and Roll-Over Protective Structure (ROPS).

A CPD is a structure that protects the operator in rollover accident by providing a CPZ under the vehicle in the event of rollover accident. Also, the CPDs absorb the impact energy and prevents the vehicle from continuously rolling in the event of rollover accident. CPDs reduce the injuries by preventing vehicle crushing and asphyxiation of the rider due to the compression on the chest or neck. The CPD doesn't require a restraint system (such as seat belt) to be effective, unlike ROPS which needs the seat belt to be effective.

Several CPDs have been designed and developed, including the U-bar, T-bar, NZ T-bar, UK U-bar, Quadbar, Lifeguard, Quadbar Flexi, Quick-fix, Air-Quad, CFMOTO, and Pro-Tec System. Some of these CPDs such as Quadbar, Lifeguard, and Quadbar Flexi are commercially available (Figure 6).

The Quadbar is a hairpin-shaped tube that extends vertically behind the ATV. It mounts on the rear tow hitch of the ATV and can be telescopically adjusted at the base (Figure 6 a). The Quadbar is made of aluminum tube and comes equipped with a flexible plastic cap along the top U shape. Quadbar Industries does not recommend installing this CPD onto a sport or recreational ATV (Robertson, 2018).

The Quadbar Flexi is a long single post CPD that extends vertically behind the ATV (Fig. 6b). It mounts to the rear tow hitch of the ATV. The Quadbar Flexi is made of a single aluminum tube with a flexible spring joint in the middle. A flexible plastic cap also covers the top of the CPD. In the event of an accident, the Quadbar Flexi will deform at the flexible joint to absorb energy and protect the operator. Quadbar Industries does not recommend towing a trailer with the Quadbar Flexi installed (Quadbar industries, 2018).

The Lifeguard is a flexible arc-shaped CPD that extends vertically from the rear of the ATV. It mounts onto the rear rack of the ATV. The flexible design of the Lifeguard allows for deflection that spreads the weight of the ATV throughout the CPD in the event of a rollover accident. The dispersal of forces within the Lifeguard allows for an operator to easily push the ATV when overturned. It is rated to support a 1,200 kg load (Lifeguard, 2018).

Figure 6. (a) Quadbar (photo credit: www.quadbar.com), (b) Quadbar Flexi (photo credit: www.quadbar.com), (c) Lifeguard (d) Quick-fix (Raphael Grzebieta, G Rechnitzer, et al., 2015) (e) MTV roll cage (f) Pro-Tec System ATV (g) Israel army ATV frame (h) CFMOTO (i) NZ T-Bar CPD (Wordley, Field, & Research, 2012), and (j) HSE U-Bar CPD (Wordley et al., 2012).

The Air-Quad is a triangular CPD that extends vertically behind the ATV (Fig. 7). It is a compact design that mounts onto the rear tow hitch of the ATV. The Air-Quad system is made of a tubular structure, gas generator, and an electronic control unit. In the event of ATV rolling, the gas generator will deploy the triangular tubing, extending the CPD both vertically and horizontally. Figure 7 shows the Air-Quad in the inactive position (a) and in the deployed position (b).

Figure 7 a. left, Air-Quad inoperative position, b. right, Air-Quad in active position (Pérez De Larraya, 2018).

Several designs of the ATV ROPS such as Dahle ROP, Johnson ROPS, and MUARC ROPS have been developed and their performance evaluated (Figure 8). Installing the ROPS, the restraint systems such as seatbelt should be applied. An ATV is an active riding device and this factor is a for not applying the restraint systems such as seat belt.

An ATV is an active riding device and this factor is another reason for not applying the restraint systems. The active riding depends on riders' action for self-protection. Active riding refers to the operator moving their pelvis (laterally and/or longitudinally) on or off the seat (vertically), while holding two handlebars and keeping legs in the footrests. Some researchers reported that active riding increased the stability of the ATV and decreases the chance of a rollover (Lock, 2015). Shortland (2013) reported the active riding can increase the stability by 10% to 30%. But for agricultural ATVs the active riding and rider separation are not considered reliable rollover risk reduction strategies (Grzebieta, Rechnitzer, Simmons, & McIntosh, 2015).

(a)

(b)

(c)

Figure 8. Three designs of ATV ROPS a) Dahle ROPS, b) Johnson ROPS, c) MUARC ROPS (Wordley et al., 2012)

5.2.3.1 OPD Installation Conclusions

Two general methods, experimental and theoretical, have been used to evaluate the performance of OPDs in ATV rollover accidents. Researchers use static, dynamic, and field-upset tests to experimentally test OPD performance in rollover accidents.

Multiple studies conducted by Dynamic Research Inc. (DRI) opposed installing OPDs onto ATVs (Munoz et al., 2007; Van Auken & Zellner, 1996; Zellner et al., 2008). Different methods were used to test these claims, including theoretical simulations on past fatal ATV accidents and full-scale field-upset tests. However, in the field upset tests, calibration of the initial ATV and dummy motion resulted in no correlation with predicted injuries. Results of these studies showed that OPDs have no statistically significant net injury benefit, or that the risk/benefit percentage was much larger than the allowed 12% limit (Zellner et al., 2008). Several studies critique the claims made by DRI, specifically the assumptions made in data input and computer simulation (Grzebieta & Achilles, 2007; Lambert, 2011; McDonald & Richardson, 2011; Stevenson, 1998).

Conversely, other studies have shown that CPDs can effectively reduce injuries during rollover accidents (Grzebieta & Achilles, 2007; Snook, 2009). Multiple agencies, including the National Institute of Occupational Safety and Health (NIOSH), Australian Centre for Agricultural Health and Safety, Australian Workers' Union, and Royal Australasian College of Surgeons recommended installing CPDs and that CPDs can reduce ATV deaths by 40% (Anonymous, 2010, 2011; Helmkamp, 2012b). Studies conducted by Meyers show the effectiveness of CPDs in rollover accidents (Myers, 2016a, 2016b, 2016c, 2017; Myers & Cole, 2016). Installing a CPD reduces the chances of life changing injuries by 70-80% (Lambert, 2011; Lower, 2013). The societal economic benefit of a CPD is $3,943, which is eight times greater than the average price of a CPD (US $478) (Myers, 2016a). The costs associated with each ATV fatality is $803,100 (Helmkamp, 2012a).

Different rates of effectiveness of CPDs have been reported. An Australian report on ATV usage on a resort found that injury rates were reduced by 90% when using a CPD (Freund, 2015). Lower (2013) noted that life changing injuries and death are decreased by 70% when using a CPD and helmet. Lambert (2011) reported that rollover accidents are reduced with a CPD, lowering injury and death rates by 80%. Furthermore, 20 individuals claimed that their lives were saved by using a CPD, while no deaths have been reported due to CPDs (Lambert, 2012).

5.2.4 Use of automatic system to notify first responders of a crash

Many ATV crashes, both on- and off-road occur in rural areas. The off-road crashes are especially problematic because of the difficulty for EMS and other first responders to locate the crash site, obtain access to the location, which may be a trail located in heavy woods, render aid to the injured and then transport the injured to the nearest hospital. Installation of technology on ATVs to automatically notify first responders that a crash has occurred and to provide information on the specific location of the crash would enable first responder to find the location of the crash, especially if it occurred off-road.

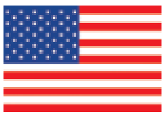
Beginning with the introduction of OnStar system by General Motors vehicles in 1997 model year Cadillacs, automakers have been installing technology to detect a crash and then automatically dial a call center that can direct emergency first responder to the scene of a crash (General Motors Heritage Center, 2019). While there is no federal requirement mandating the use of this technology, motor vehicle manufacturers have voluntarily been installing them in vehicles. In the European Union, there is a rule that will require passenger cars to have eCall (Emergency-Call) devices installed as of April 2018 (European Commission, 2018). And in December 2017, the European Association of Motorcycle Manufacturers (ACEM) announced it is creating a task force to look at installing such devices in motorcycles (European Association of Motorcycle Manufacturers, 2017). Many of the ACEM manufacturers also make ATVs and side-by-side ATVs (BRP, Honda, Kawasaki, Polaris, Suzuki, and Yamaha).

Farm Angel, a New Zealand based company, already markets a product to be installed on ATVs and side-by-side ATVs that will automatically send a signal if it detects that the rider has been in a crash. In addition, the device has a geo-fencing capability to limit the areas in which an ATV or side-by-side ATV can be ridden. Another benefit is the system can measure the speed and acceleration of the vehicle and thus help employers identify employees that are engaging in risky riding (Blackhawk, 2015)

5.3 The administrative authority

This section includes rules and standards around the world and in the United States regarding ATVs and Off- Highway Vehicles.

5.3.1 United States



In the United States, all- terrain vehicles (ATVs) are regulated by the Consumer Product Safety Commission (CPSC) and not by the U.S. Department of Transportation, which regulates motor vehicles designed to be used on public roads. The CPSC can either issue a mandatory standard developed by its staff or the CPSC can adopt an industry-developed standard.

In the case of ATVs, the CPSC currently has adopted the 2010 voluntary standard developed by the Specialty Vehicle Institute of America (SVIA) and the American National Standards Institute (ANSI) (ANSI/SVIA, 2017). In 2008, the U.S. Congress passed the Consumer Product Safety Commission Improvement Act, which banned the import and distribution of three-wheeled ATVs. The Act also directed CPSC to upgrade the existing ATV standard, including considering whether to set upgraded requirements for the dynamic stability of ATVs (Consumer Product Safety Commission, 2008). In September 2013, the CPSC proposed adopting the 2017 version of the ANSI/SVIA standard (Consumer Product Safety Commission, 2017) It also continued to evaluate upgrades to vehicle stability and occupant protection for ATVs. As of October 2018, CPSC has not issued a final rule on that proposal.

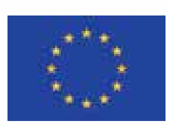
In the case of Recreational Off-Highway Vehicles also known as side-by-side ATVs or Utility Terrain Vehicles, CPSC issued an Advanced Notice of Proposed Rulemaking in October 2009 saying the Commission was considering whether ROVs present an unreasonable risk of injury and death (Consumer Product Safety Commission, 2009). In November 2017, the Commission published a Notice of Proposed Rulemaking setting out a safety standard for ROVs (Consumer Product Safety Commission, 2014)

In November 2016, CPSC staff sent a briefing package to the Commissioners evaluating the voluntary standard created by Recreational Off-Highway Vehicle Association (ROHVA) and ANSI standard and recommend terminating the proposed mandatory standard. In January 2017, the Commission voted not to terminate the rulemaking. And currently CPS staff is continuing its evaluation of the ROHVA and ANSI ROV standard (U.S. Office of Management and Budget, 2018).

5.3.2 Canada

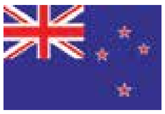
In Canada, there are no federal standards for ATVs and Side-by-Side ATVs. Instead, there are industry -developed standards for those vehicles adopted by the Canadian Off-Highway Vehicle Distributors Council (COHV) The COHV 2-2017 standard for Recreational Off-Highway Vehicles adopts the ROHVA-ANSI standard 1-2016. (Canadian Off-Highway Vehicle Distributors Council, 2017) The COHV standard for Four Wheel ATVs (COHV 1- 2012) adopts ANSI/SVIA 1-2012 standard (Canadian Off-Highway Vehicle Distributors Council, 2012).

5.3.3 Europe



In Europe, vehicle safety is regulated by international standards and standards set by the European Union (EU) and the United Nations Economic Commission for Europe (European Commission, 2019). The EU has adopted a regulation that set performance requirements for quadricycles which includes which includes ATVs and side-by-side ATVs (European Union, 2013). The EU requirements are like the CPSC requirements and the industry-develop voluntary standards in the U.S. The CPSC regulations and the industry voluntary standards don't address antilock brake systems on off-highway vehicle, but the EU regulation permits, but does not require, the use of ABS on off-highway vehicles.

5.3.4 New Zealand



In 1998 the New Zealand Occupational Safety and Health Service of the Department of Labour published the "Guidelines for the Design, Construction and Installation of Rollover Protective Structures (ROPS) for All Terrain Vehicles". It is not known if any of the commercial ATV CPDs are using these guidelines for their design.

5.3.5 Australia

The Australian Consumer and Competition Commission (ACCA), the equivalent of the CPSC, has issued an issue paper asking for public comments about setting a safety standard for those vehicles and creating a safety rating program for them (Australian Competition & Consumer Commission, 2017b). Comments submitted on the proposals are posted on the ACCC website (Australian Competition & Consumer Commission, 2017a). The Australian Government passed a new standard to improve the safety of ATV (Australian Government, 2019). Based on this standard within 12 months (Since oct 2019), all new ATVS will be required to:

- have a warning label alerting rider to the risk of roll over
- meet US or European standards (performance of components like brakes, suspension, throttle and clutch)
- test for stability and display the result on a hang tag attached to the bike at point of sale.

Also, within 24 months (since Oct 2019), all new general use model (utility) ATVs will be required to:

- be fitted with, or have integrated into the design an OPD
- meet minimum stability requirements

The Australian Competition and Consumer Commission (ACCC) will also work alongside Standards Australia as industry develops their own specifications for the safety of OPD (Australian Government, 2019).

5.3.6 Israel

Israel requires ATVs to have a device called a safety frame installed on the rear of the vehicle which is designed to prevent the ATV from crushing the rider underneath the ATV in the event of a front, side or backwards rollover. The manufacture and installation of the safety frames are required to be done by a manufacturer approved by the Ministry of Transport under the supervision of a qualified test laboratory (Israel Ministry of Transport, 2005). The safety frame (also call a back arch) is a safety feature often called a Crush Protection Device (CPD). The Standards Institute of Israel has conducted testing of the CPD in three types of rollovers: a backward rollover, a forward rollover and a side way roll-over while driving in a circle. The tests were done both with and without the CPD installed on the ATV. The researchers concluded "that the injuries caused to the rider during the rollover without the back arch , were more severe than during the roll-over with the back arch."(The Standards Institute of Israel, 1998). Technical specifications for testing and mounting of Israeli safety frames for ATV's are provided below:

5.3.6.1 General

Specifications for the production and installation of safety frames behind the driver's seat across the width of the ATV.

5.3.6.2 The specifications of the structure

The safety frame shall be installed on the ATV by clamps with mounting bolts and safeties, without any drilling or welding. The frame shall withstand the following loads without any left-out distortion in the following loads.

- A vertical load equivalent to 1.5 times the weight of the ATV.
- A horizontal load. in the direction of the ATV's longitudinal axis, equivalent to 0.15 times the weight of the ATV.
- A horizontal load, in the direction perpendicular to the ATV's longitudinal axis parallel to the ground surface, equivalent to 0.65 times the weight of the ATV.

5.3.6.3 Minimum dimensions of the frame and its location:

The minimum height of the internal part of the frame, above the seat (unloaded) shall be 100 cm. The minimum internal width of the frame shall be at least 75 cm (measured at a height of 50 cm. above the seat. The frame shall be constructed as one piece (for example a bent pipe) and shall not have any sharp comers. The horizontal top part of the frame shall be coated all around with a flexible material as follows:

- The thickness of the flexible material shall be not less than 20 mm.
- The hardness of the padding shall be between 40 and 50 units, measured by the SHORE method.

The frame, including the mounting hardware, shall be protected against corrosion. The mounting bolts shall be high-strength steel bolts ("80" bolts). The welding of the safety frame shall be done only at the frame's manufacturer, and by welders authorized according to Israeli Standard 127 (part 2 or 1). The frame welding process, if there is one, shall be carried out according to a process, which was approved, and authorized, as fully conforming to the requirements of Israel Standard 127.

5.3.6.4 Testing

The test shall include:

- Defined prototype - characterized by proper technical drawings.
- Mathematical analysis.
- Defined prototype- characterized by testing at an accredited laboratory including actual loading test.

5.3.6.5 Administrative requirements

The manufacturer of the ATV frames shall have a valid production license from the Ministry of Transport. which authorizes it to produce and install safety frames. The manufacturer shall provide the accredited laboratory detailed technical drawings, appropriate calculations, and a prototype for each model of safety frame it produces. before and after mounting it on the ATV. Following the test and authorization by the laboratory, the laboratory shall issue the manufacturer an appropriate certificate, including a signed drawing, and send copies to the Homologation department. The manufacturer must order from an accredited laboratory at least four visits per year, being made without prior notice, whereby the purpose of the visits is to ensure that the frames manufactured and installed by the manufacturer match the approved prototypes. Should any exception be found, the manufacturer shall have to recall the vehicles on which the frame was fitted and install it appropriately.

Each safety frame shall be marked with a permanent marking. including the manufacturer's name, the frame model, the serial number of the frame, and the license (or chassis) number of the ATV. on which the frame is mounted and approved with a certificate of issued by a manufacturer authorized by the Ministry of Transport and under the supervision of an accredited laboratory.

5.3.6.6 Authorized installers

The safety frame shall be mounted on the ATV by any manufacturer authorized for this purpose by the Ministry of Transport and under the supervision of an accredited laboratory.

5.4 The training and personal protective equipment

In this section the available occupational training programs in the united states and the recommended personal protective equipment are discussed.

5.4.1 Available occupational training programs

The ATV Safety Institute (ASI) is within a division of the Specialty Vehicle Institute of America. Established in 1988, this non-profit group came together for the sole purposes of safety education and awareness. The ASI mission is to promote the safe and responsible use of ATV's thereby reducing crashes and injuries that may result from improper operation by the rider (ATV Safety Institute, 2007, 2017).

Within the larger trade association, the Specialty Vehicle Institute of America (SVIA) is a not-for-profit organization sponsored by ATV manufacturers, including Artic Cat, BRP, Bush Hog, CROSSRUNNER, Honda, John Deere, Kawasaki, KTM, KYMCO, Polaris, Suzuki, Tomberlin, and Yamaha. Besides safety education and public awareness campaigns, the organization serves as a resource for ATV research, statistics and vehicle standards. They also provide support language to develop public policy for state legislation. Through their member companies, SVIA offers free hands-on training to any individual who purchases a new ATV, including the owners' family members. Other ATV operators are able to take the training for a reasonable fee. Their national training office can be reached at www.atvsafety.org or 1-800-887-2887.

A free ATV RiderCourse℠ provided by ASI, is available in the U.S. to any new ATV owner upon initial purchase of the vehicle. This training is also available for a nominal fee, when operators do not purchase new machines. In some states, this course is required in order to ride on public land. Approximately 2,100 ASI instructors are licensed and authorized to teach the course, with a local registry maintained at ATV dealerships. These instructors must keep their license current, by attending refresher training programs through ASI with approximate course fees of $800 every 5 years.

Students enrolled in the ATV RiderCourse must be at least six years old. Additional requirements are put in place for youth riders, whereby those under 16 years old are required to be on an appropriate-sized ATV for their age (ATV Safety Institute, 2011). Parents are encouraged to attend the courses for students 12-16 years old and required to be in attendance when riders are 6-12 years old. Participants older than 16 years of age, are permitted to enroll and ride adult-sized ATV's. In cases where one vehicle is purchased for family use, the entire family is encouraged to attend the course.

The ATV RiderCourse is 4-6 hours of intense training, focused on safety information and riding techniques. The hands-on approach offers a variety of lessons teaching personal protective gear, understanding local riding ordinances, and environmental respect and responsibility for the land. The rider active modules include starting and stopping, turning, negotiating hills, emergency stopping and swerving, and riding over obstacles. Some courses will include riding with add-on equipment.

sized, so too are specialty situations within the job. Different aspects are addressed within military, forestry, and public utility workers training programs. The same holds true for the unique application of ATV's used in agricultural environments. On the farm, add-on equipment and towed implements affect the machine's operation and center of gravity. Besides training, agricultural employers should create and maintain an ATV/UTV safety policy, which mandates training and an annual refresher course.

Table 3. Available sources regarding the operation and riding techniques

Title of publication	***Where to access it***
Tips and Practice Guide for the ATV Rider	ATV Safety Institute (2008) http://www.atv-youth.org/ATVresourcesPage/Tips_2%20Up_3-20-08_Final.pdf
ATV Safety: 4-H Project Leaders Guide, publication booklet 4-H 555	The Ohio State University Extension Publications (2019) http://estore.osu-extension.org
Utility-Terrain Vehicle Operator Training Course: Instructor's Guide	United States Department of Agriculture (2011) www.fs.fed.us/t-d/pubs/pdfpubs/pdf11672828/pdf11672828dpi300.pdf
ATV Safety on the Farm (video)	(The Ohio State University Extension Publications, 2009) http://estore.osu-extension.org

All ATV riders are encouraged to consult their vehicle's operator manual for proper instruction and understanding of their machine. ATV models vary in engine size specifications, throttle speed regulators, braking, clutch and gearshift controls. Additional resources are available to learn operation and riding techniques, regardless of operators' age. See table 3 for a list of training curriculum.

Training programs for employees operating ATV and UTV's are available within certain occupations. Similar to the ASI courses where basic safety operation and skills are empha-

5.4.2 Protective Gear for ATVs

For comfort and safety, there are recommended protective items to be worn while operating ATV's. Not only will these items protect the rider from the environment, but also in case of a spill.

5.4.2.1 Helmet

An approved motorized helmet is required. In the U.S., two agencies meet helmet certification standards: the Snell Memorial Foundation or Department of Transportation (DOT). The European standard is denoted as ECE, P, NP or

J. The Japan standard is JIS T. This certification assures the rider the helmet has a durable outer shell to resist penetration and abrasion, and an inner lining that helps absorb impact to the brain. Helmet testing includes criteria for penetration, impact, chin strap retention, and peripheral vision.

Helmets will vary in size, shape and weight. For this reason, each rider is recommended to have his or her own helmet. Helmets can be fitted at the dealership, and chin straps ensure they stay in place while riding.

5.4.2.2 Eye Protection

Full face helmets will be equipped with a built-in face shield, including shatter-proof glass. Other helmets are open-faced and will require goggles. The materials in ATV eye wear is typically manufactured with a hard-coated polycarbonate. The lens must be able to endure impact from flying debris, and include a standard stamped into the lens of z87 or VESC 8 (V-8).

Helmet straps must fit securely over the exterior shell of the helmet, and be replaced when the strap looses elasticity and ability to hold the eye gear in place.

5.4.2.3 Gloves

Hand protection is necessary for grip and control of the vehicle. Some gloves offer additional padding and anti-vibration materials to reduce strain and increase comfort for the driver. At the very least, gloves provide protection from the elements in the riding environment.

5.4.2.4 Boots

The proper footwear for ATV riders is a low heel, and over-the-ankle styled shoe or boot. Durable outer material is also recommended for the elements. Motorcycle boots offer maximum protection against heat, and other road encountered obstacles. These boots are at least 8-inches high, with some styles fully covering the shin (American Motorcyclist Association, 2018).

5.4.2.5 Protective Clothing

Long pants and long-sleeved shirts are recommended. These items offer protection from debris and the environment. Other protective clothing includes chest protectors, neck braces, and knee braces. Depending on the nature of the environment and terrain, these items offer the rider additional comfort and protection.

6. Youth and ATVs in the Agricultural Industry

The *Blueprint for Protecting Children in Agriculture:* The 2012 National Action Plan (Lee, Gallagher, Liebman, Miller, & Marlenga, 2012) was a call to action. The Blueprint encouraged child advocates, farm organizations, safety practitioners, researchers, policy makers, funding agencies, and corporate sponsors to place what was and is collectively known about the health and safety of young workers in the agricultural industry into practice. One of the goals placed a priority on interventions that would address the causes of nonfatal and fatal injuries incurred while operating ATVs.

6.1 Regulation of Youth Labor in the Agricultural Industry

Federal regulation of child labor dates back to the short-lived Keating-Owen bill of 1916 (Miller, 2012). Regulation of the industrial environment began with the Fair Labor Standards Act (FLSA) in 1938. The Act set a minimum age of 16 for nonagricultural work and restricted work in hazardous jobs (Miller, 2012). Miller notes, the constraints placed on the non-agriculture industry were more restrictive than those placed on the agricultural community.

In 1968, the FLSA was amended to include the Hazardous Occupations Orders for Agriculture, also known as AgHOs (Garvey, Murphy, Yoder, & Hilton, 2008). According to Miller, the Orders permitted youth as young as 16 to perform tasks in the agricultural industry known to be hazardous. Certain exemptions within the AgHOs made it possible for children 12 and older to work on farms and ranches owned by their parents or guardians or other farms (DeRoo & Rautiainen, 2000). Children, as young as 14 years, were permitted to work on farms and ranches if they received training and certification in approved tractor and farm machinery certification programs(Garvey et al., 2008).

6.2 Youth Agricultural Safety Education, Training, and Certification

DeRoo and Rautiainen (2000) identified and reviewed 25 studies that involved farm safety education, interventions, environmental and equipment modifications, farm visits and audits, assessments of short- and medium-term impacts, and changes in incidences of injuries. They concluded more evaluation of farm safety intervention programs was needed.

(Neves et al., 2018) in their review of literature related to ATV use, injury, fatality, exposure assessment, risk estimation and interventions confirmed the risk of injury and fatality was greatest in the agricultural community.

The concern for farm safety gained traction in the 1990s. The demand for preventive measures grew with pressure from the farming community and health care fields (DeRoo & Rautiainen, 2000). Self-imposed regulations, safety education, or modifications to the work environment or equipment to assure the health and safety of workers were reliant on historically voluntary safety education and injury prevention programs (DeRoo & Rautiainen, 2000). Farmers aware of hazards decline to make changes based on time, inclination to change behaviors, cost, difficulty, or probability of injuries occurring (DeRoo & Rautiainen, 2000). Given the reluctance of farmers to engage or invest in risk avoidance protocols, the opportunity for intentional or unintentional exploitation of the AgHOs is always present (Garvey et al., 2008).

Individual states are responsible for providing tractor and machinery education, training, and certification programs (Garvey et al., 2008). Several were based on the AgHOs. Some of the training programs used the 4-H tractor operations manuals (Garvey et al., 2008). These programs fell into disrepair through lack of interest and implementation (National Safe Tractor and Machinery Operations Program, 2013).

These circumstances set into motion a concerted effort by Pennsylvania State University, Ohio State University, and the National Safety Council to add stability to intrastate and interstate tractor and machinery certification programs (Garvey et al., 2008). The framers of the NSTMOP discovered a great degree of variation in the quality and quantity of youth certification programs. There appeared to be no standardization of teaching materials, instructional hours, forms of instruction, testing procedures, or skills assessments (National Safe Tractor and Machinery Operations Program, 2013).

A nationwide tractor and machinery operation program was needed to "...provide uniform instructional materials that could be economically produced, and instill confidence because training and certification procedures would be validated through standardized testing procedures" (Garvey et al., 2008). The NSTMOP was operationalized in 2004. Thirty-eight states are known to use the NSTMOP for education, training, and certification of youth workers (Newell, 2018).

6.3 Limitations to ATV Safety Education, Training, and Certification in the Agricultural Industry

Most states require some form of minimum certification for youth to ride on public lands. The same is not true when it comes to youth operating ATVs on private lands.

The Oregon ATV Safety Youth Rider Endorsement Program (Oregon State University Extension Services, 2011) offers youth operator training. Youth learn mental and physical skills necessary to ride on state controlled property based on minimum standards established by the Oregon Parks and Recreation Department. The Oregon program has an on-line education pre-requisite to hands-on training. The size of ATV used in training is based on rider fit.

The ATV Basic RiderCourse training provided by the ATV Safety Institute is another example (Oregon State University Extension Services, 2011). Rather than rider fit, the course relies on manufacturer recommended age groups to establish the size of ATV used in training.

The collaborative efforts of Colorado State University and Montana State University resulted in ATV safety education for agricultural producers and certification of Extension agents to deliver ASI Basic RiderCourse instruction to farmers and ranchers (High Plains Intermountain Center for Agricultural Health & Safety, 2016).

However, programs like these lack the kind of national standardization necessary to test the advanced mental and physical skills needed to safely and responsibly use ATVs in the agricultural setting (e.g. personal protective equipment; riding smart, ethically, and safely; starting and stopping; quick stops in straight lines and curves; turning and weaving; evasive moves; obstacles; ascending and descending slopes; traversing hills; towing; K and U turns on slopes, carrying loads; loading and unloading).

Moreover, voluntary compliance with recommendations, best practices, regulations or equipment modifications in an exempt industry is not necessarily an effective intervention strategy in agricultural communities.

Additionally, a low percentage of youth participate in ATV training, a high percentage of youth are not able to access ATV training, youth are not inclined to wear helmets or other protective gear, youth frequently ride with others on ATVs, and youth frequently ride on paved roads (Burgus, Madsen, Sanderson, & Rautiainen, 2009).

The (National Safe Tractor and Machinery Operations Program, 2013) materials integrate tractor and ATV education, training, and certification. However, it lacks appropriate coverage of ATV topics. The use of ATVs is relegated to a four pages within a section devoted to material handling. It covers stability, suspension, drive lines, and power and speed. Bulleted points cover engine size, age recommendations, passengers, machine limitations, personal protective equipment, and risk avoidance. The information presented is not part of the minimum core content area which is used to prepare written tests. There is no driving test or opportunity for hands-on skill development regarding connecting and using implements.

6.4 Rider Fit Versus Operator Age and Engine Displacement

Conventional wisdom regarding youth and ATVs suggests that the age of the operator is correlated to safer and more responsible operation of ATVs. However, physical size and rider cognition skills may prove to be more appropriate gages when matching operator to an ATV. The average height for boys and girls 15 years of age is 5 feet 7 inches (Center for Disease Control, 2000a) and 5 feet 3 inches (Center for Disease Control, 2000b) respectively. Yet, for boys and girls over 6 feet tall, at the age of fifteen or even younger, sheer size imposes certain operational challenges and health risks.

In the absence of an integrated Tractor & ATV safety education, training, and certification program, the agricultural community can employ best practices by assuring youth workers can meet the following minimum standards (White, Bryant, & Lane, 2016).

Brake Reach: With hands placed in the normal operating position and fingers straight out, the first joint (from the tip) of the middle finger will extend beyond the brake lever and clutch. See Figure 9.

Figure 9. Illustration Used with Permission (IPCH, 2018).

Leg Length: While sitting and with their feet on the pegs, the knee must be bent at least 45 degrees. See figure 10. Grip Reach: While sitting upright on the quad with hands on the handlebars and not leaning forward, there must be a distinct angle between the upper arm and the forearm. See figure 10 and 11.

Figure 10. Illustration Used with Permission (IPCH, 2018).

Turning Reach: The operator must be able to turn the handlebars from lock to lock while maintaining grip on the handlebars and maintaining throttle and brake control. See figure 11.

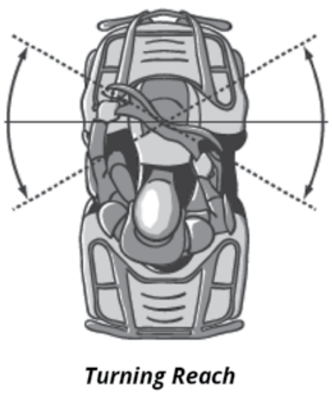


Figure 11. Illustration Used with Permission (IPCH, 2018)

6.5 Implications for Extension Action

Oregon State University was unsuccessful in its bid to receive a 2013 Youth Safety Education and Certification Competitive Grant through the United States Department of Agriculture, National Institute of Food and Agriculture. It outlined a two-year, $478,000 project to fill a gap in the land grant university system, 4-H Extension Service, and high school vocational agriculture programs by initiating a National Safe ATV and Machinery Operation Program that paralleled the NSTMOP.

The curriculum (White, Lane, Bryant, Anderson, & Wells, 2014) consists of sections devoted to student orientation and briefing, equipment evaluation, mental riding exercises, pre-riding exercises, and fifteen physical riding skills (i.e. personal protective equipment; riding smart, ethically, and safely; starting and stopping; quick stops in straight lines and curves; turning and weaving; evasive moves; obstacles; ascending and descending slopes; traversing hills; towing; K and U turns on slopes, carrying loads; loading and unloading).

The use of ATVs in the agricultural industry by youth appears to be a growing national pediatric morbidity and mortality issue. Without a nationally organized collaborative effort, states, much like Oregon, will start to independently develop training and intervention programs to address the use of ATVs in the agricultural industry. These programs will likely function without standardization of teaching materials, instructional hours, forms of instruction, testing procedures, or skills assessments. Extension is posed to develop and deliver ATV education, training, and certification in concert with tractor and machinery operation education, training, and certification.

7. Future Research and Work

a) Evaluate agricultural ATV (riding condition and accidents)

There are several differences between recreational and agricultural ATV accidents, which include types of accidents and resulting injuries, riding speeds, added loads, and attachments to the ATV. McIntosh et al. (2016) reported a very clear pattern of recreational and farm work-related deaths: ATV rollovers (farm worker, 85%; recreational rider, 55%) with the operator pinned under the ATV (farm worker, 68%; recreational rider, 30%) and death by asphyxia (farm worker, 42%; recreational rider, 11%). By contrast, recreational riders suffered impact injuries to the head and chest when riding fast, losing control, being ejected, and crashing into a stationary or moving object (McIntosh et al., 2016). Most workers (50 - 75%) had one or more attachments fitted to the ATV, while only a few of the recreational riders had an attachment on their ATVs (25 - 33%) (McIntosh et al., 2016). There is an obvious need to distinguish and treat the safety requirements for farm ATV differently compared to the recreational ATV. Also, a little number of studies specifically have evaluated the farm ATV. There is a need to specifically evaluate farm ATV as base for future studies.

b) Develop a test station to evaluate safety and operation criteria of ATV and OPD (farm condition)

Several test stations have been developed to evaluate performance of ATV and OPD in rollover accidents, but a little number of them simulate the agricultural ATV rollover accidents. There is a need to develop a test station based on the farm ATV (riding and accident) condition.

c) Design a new OPD

Researchers recommended to conduct more experimental studies to evaluate the performance of different designs of CPD and ROPS in rollover accidents and develop new designs of CPDs (Grzebieta, Rechnitzer, Simmons, & McIntosh, 2015).There are three reasons opposing CPD/ ROPS installation on ATV, 1) The injuries caused by impact between the CPD/ROPS and the operator, 2) Operator to be caught between the ROPS/CPD and ground surface, 3) The CPD/ROPS impede operator rapid separation from the vehicle (Zellner et al., 2013). The new design of CPD/ROPS should minimize or eliminate those three reasons.

d) Develop technical standards for evaluating OPD performance

Although many ATV roll bars are sold in the US, but there is not officially accepted standard to test the ATV roll bar performance. Also, the ATV Safety Institute in the United State as along with the Specialty Vehicle Institute of America (SVIA) doesn't approve mounting roll bars on ATVs. One guideline testing ATV OPD in New Zealand has been developed but has not been approved (New Zealand occupational safety and health service, 1998). Also, one standard for static test of ATV frame was developed in Israel (Zeiri, E. 2004).

ANSI/SVIA 1-2017 is a voluntary standard for four-wheel ATVs and is a revision of original American national standard ANSI/SVIA 1-1990. The standard was developed by members of the SVIA. This standard address design, configuration, and performance aspects of ATVs, including mechanical suspension and pitch stability. But there is no standard in the United States addressing the ATV OPD (ANSI/SVIA, 2017).

The applied standard test for testing ATV CPD varies from tractor tests (ISO 5700) to motorcycle (ISO 13232-5). Several standards have been developed for testing tractors ROPS and nearly all of them required an experimental test rather than a theoretical test. Among the experimental test methods (static, dynamic, and field-upset tests) the field-upset test can simulate the most realistic accident condition. It is recommended to develop a field-upset test based on the most prevalent occupational rollover accident causes.

e) Rules to require employers, including farmers, to fit OPD to their ATV

OPD installation on utility ATV is mandatory in several countries including, New Zealand

(Aotearoa, 2019) and Israel (Zeiri, 2004) and will be mandatory in Australia (Australian Government, 2019). Although many OPDs are sold in the US, there is no federal or state regulation related to CPD in the United States. Also, the ATV Safety Institute in the United States as along with the Specialty Vehicle Institute of America (SVIA) doesn't approve mounting roll bars on ATVs.

Israel's Ministry of Transport required the mandatory fitting of safety frame on all ATVs. The Australian Government passed a new standard to improve the safety of ATV (Australian Government, 2019). Based on this standard within 24 months (Since oct 2019), all new general use model (utility) ATVs will be required to be fitted with or have integrated into the design an OPD.

If experimental test results based on the farm condition confirm the effectives of CPD in ATV rollover incidents, there should be a rule that required the mandatory fitting of CPD on agricultural ATV in the United States.

f) ATV safety equipment and CPD rebates program in the United States

New Zealand government (Accident Compensation Corporation, 2019) and several states in Australia provide rebates to purchase safety equipment and CPD for utility ATVs (NSW Farmers, 2018; Victorian Farmers Federation, 2017). The Same program should be developed in the United States.

g) Developing an ATV safety and health training program for children

The evidence points to increased morbidity and mortality rates among the youth population using ATVs on the nation's farms and ranches. What was needed for youth tractor safety also holds true for ATV safety in the agricultural industry. While the standards for improved education, active skill development, and driving competency related to tractors are vastly improved because of the NSTMOP; ATVs add to the dangers faced by youth in an industry that Miller (2012) and Lee et al. (2012) refer to as the most dangerous of environments.

There is a critical need for a nationally recognized ATV safety and machinery operations program that formalizes instructor training, provides uniform instructional materials, is economically produced, is validated through standardized testing, and establishes a data base for ongoing evaluation of risks, interventions, and behavioral changes.

h) Improve the stability of ATV

Due to the relatively high center of gravity and small tread width and wheelbase, the lateral and longitudinal static stability angles are low, increasing the possibility of rollovers. Applying different technologies to improve the stability of ATV such as developing self-balancing human transporter (like Segway Centaur), having two-wheel ATV (increase the track width), and using more advanced suspension system (such as new systems on ROVs). However, the suggested technical advances may not be practical or efficient for ATVs and should be evaluated in advance.

8. Recommendations

1- NIOSH should fund studies of ATV use and associated injuries in agriculture in cooperation with CPSC.

2- CPSC should not exclude agricultural use of ATVs from their database as occupational as is done with tractors (which results in exclusion of avocational—consumer—uses of tractors).

3- CPSC should compare crash characteristics and use of ATVs to better understand their use in agriculture.

4- CPSC should surveil and compare the incident record of side-by-side vehicles with ATVs so as to determine if they are safe alternatives to ATVs in agriculture.

5- The differences between Utility (Agricultural) ATVs and Sport ATVs are well defined and can be used to distinguish between the two. Also, the differences between the accidents and the injuries in recreational and agricultural ATV accidents are significant. There is an obvious need to distinguish and treat the safety requirements for agricultural ATV differently compared to the recreational ATV

6- Due to the relatively high center of gravity and small tread width and wheelbase, the lateral and longitudinal static stability angles are low, increasing the possibility of rollovers. New technologies should be developed, evaluated, and applied to improve the stability of ATV.

7- Although there are some contradictions in results of previous studies regarding the effectiveness of CPDs in rollover accidents, majority of experimental studies showed that CPDs can effectively protect the operator in low speed accidents (such as agricultural accidents). Several governmental institutes in the United States and Australia confirm the effectiveness of CPDs in ATV rollover accidents, such as Work-Safe Victoria in Australia and Upper Midwest Agricultural Safety and Health (Upper Midwest Agricultural Safety and Health, 2017) and The National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS, 2018) in the United Sates. Although several institutes such as SVIA in the United States doesn't recommend installing CPDs on ATVs.

8- Developing an effective solution for agricultural ATV incidents, then develop standard to implement the solution and having experimental tests to evaluate the solution.

9- Currently ATV ROPS or CPD Standards are not well defined or applied. The current Israeli standard addressing ATV safety frames (ROPS) has the most application. There is a need to develop new standard to evaluate performance of OPD in ATV rollover accidents.

10- A National Safe ATV and Machinery Operation Program is needed that parallels the National Safe Tractor and Machinery Operation Program. Education and training opportunities should be developed and implemented that assess youth mental and physical riding competencies. At a minimum, youth should be able to demonstrate their use of personal protective equipment; ability to ride smart, ethically, and safely; prove their capacity to operate an ATV by starting and stopping, coming quick stops in straight lines and curves, turning and weaving, evading obstacles, ascending and descending slopes, traversing hills, towing equipment, completing K and U turns on slopes, and carrying loads. Without a nationally organized collaborative effort, states will start to independently develop training and intervention programs without standardization of teaching materials, instructional hours, forms of instruction, testing procedures, or skills assessments.

11- Based on the success of the New Car Assessment Programs in influencing vehicle manufactures to improve the crashworthiness of their vehicles, a similar program should be developed to measure and rate the stability and crashworthiness of ATV. For example, ATVs equipped with OPD could be tested to determine how well the protect the occupants in a rollover crash.

12- Targeted interventions are needed to address the higher rates of youth mortality associated with ATV use. This work may focus on engineering mechanism to improve the safety of ATV operation by youth such as limiting speeds or monitoring devices to allow parental control over the machine. The utilization of GPS and accelerometer sensors as standard equipment show potential for alerting medical services or rescue personnel of a crash incident. This technology has been successfully implemented in motor vehicle applications such as smart phone apps like the SOSmart®. The OnStar® on board vehicle security system may show potential for adaptation with ATV and UTV vehicles. This could allow parental control of the vehicle and track/report youth driving behaviors. Much like over-the-road trucks, equipment manufactures could develop electronically govern vehicle speed and thereby reducing the risk of over speeding and vehicle overturns.

13- Other considerations may include engineering focused on PPE or helmet enabling devices for ATV or UTV vehicles. This technology would prevent the use or startup of machinery unless the operator properly dons the necessary PPE.

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Skjolaas, Cheryl A .... University of Wisconsin
Slocombe, John .... Kansas State University
Yoder, Aaron .... University of Nebraska

Other Contributing Authors

Denning, Gerene ....University of Iowa
Jennissen, Charles ....University of Iowa
Myers, Melvin .... Emory University
Oesch, Stephen ....Retired Highway and Motor Vehicle Safety Attorney
White, David ....Oregon State University

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