

UC Davis

UC Davis Previously Published Works

Title

A Systematic Review of Youth and All-Terrain Vehicles Safety in Agriculture

Permalink

<https://escholarship.org/uc/item/4zv1g9m5>

Journal

Journal of Agromedicine, 28(2)

ISSN

1059-924X

Authors

Khorsandi, Farzaneh
De Moura Araujo, Guilherme
Fathallah, Fadi

Publication Date

2023-04-01

DOI

10.1080/1059924x.2022.2155747

Peer reviewed



A Systematic Review of Youth and All-Terrain Vehicles Safety in Agriculture

Farzaneh Khorsandi, Guilherme De Moura Araujo & Fadi Fathallah

To cite this article: Farzaneh Khorsandi, Guilherme De Moura Araujo & Fadi Fathallah (2023) A Systematic Review of Youth and All-Terrain Vehicles Safety in Agriculture, Journal of Agromedicine, 28:2, 254-276, DOI: [10.1080/1059924X.2022.2155747](https://doi.org/10.1080/1059924X.2022.2155747)

To link to this article: <https://doi.org/10.1080/1059924X.2022.2155747>



© 2022 The Author(s). Published by Informa UK Limited, trading as Taylor & Francis Group.



Published online: 20 Dec 2022.



Submit your article to this journal [↗](#)



Article views: 464



View related articles [↗](#)



View Crossmark data [↗](#)

A Systematic Review of Youth and All-Terrain Vehicles Safety in Agriculture

Farzaneh Khorsandi^a, Guilherme De Moura Araujo^b, and Fadi Fathallah^b

^aCooperative Extension in Agricultural Safety and Health, Department of Biological and Agricultural Engineering, University of California, Davis, Davis, California, USA; ^bDepartment of Biological and Agricultural Engineering, University of California, Davis, Davis, California, USA

ABSTRACT

All-terrain vehicle (ATV) incidents are one of the leading causes of injuries and fatalities among youth in the agricultural industry. It has been hypothesized that many youth-related ATV incidents occur because children ride ATVs that do not fit their capabilities and are not following basic safe riding practices. In addition, various ATV safety guidelines regarding youth (e.g., CPSC, ANSI/SVIA, ASI) are inconsistent and may not align with state or local laws. To the best of our knowledge, no comprehensive studies have compared the physical and mental requirements for riding ATVs and the youth's capabilities to ride ATVs safely. Consequently, there are no scientific-based recommendations for age limitation, physical and mental capabilities, and safety requirements for youth to ride ATVs safely. Thus, there is a need to review the available sources related to youth safety and ATVs in the agricultural industry, identify the research voids, and recommend modifications to current ATV guidelines. This study conducted a systematic review of available ATV-related studies, standards, guidelines, and laws to establish better-informed minimum age, physical and mental capabilities, and safety requirements for youths to ride ATVs on the farm.

KEYWORDS

Age limitation; agriculture; ATV; mental capabilities; physical capabilities; safety

Background

As an industry, agriculture has one of the highest proportions of youth workers. NIOSH reported that approximately 893,000 youth lived on farms (in the present manuscript, the term “on farms” also includes “on ranches”) in 2014, and more than half (51%) worked on their family's farms.¹ Across all ages,² the agricultural industry is among the most dangerous occupational sector in the United States and is the most dangerous industry for youth.³ Among youth workers (<16 years), the number of worker fatalities in agriculture has been consistently higher than in all non-agricultural industries combined.³ On average, approximately 33 children in the U.S. are injured in agriculture-related incidents each day;¹ every 3 days, a child dies in an agriculture-related event.⁴

The economic, social, and legal/political conditions that have historically surrounded U.S. agriculture may partially explain this situation.^{5,6} Often, farm parents began working at a very young age and expected their children to do

the same. Economically, farmers have high financial and workload pressures, which push them to call for all family members' contributions to the farm work. Politically, the virtual absence of federal safety regulations on small farms precludes any meaningful oversight with regard to youth exposure to occupational hazards. For instance, most farms with 10 or fewer employed workers and no temporary labor camp during the last 12 months are exempt from OSHA's federal regulations.⁷ As a result, only about 7% of U.S. farms are required to comply with OSHA standards and regulations.⁸

Farms are also exempt from some child labor laws and occupational safety regulations.⁹ Although employing youth under 16 years is generally not permitted by the Child Labor Act, youth employed on farms are exempted from that restriction. The Fair Labor Standards Act was amended in 1968 to include the Hazardous Occupations Orders for Agriculture, also known as AgHOs.¹⁰ However, certain exemptions made it

possible for youth 12 years-of-age and older to be hired by farmers with parental permission and under certain task restrictions.¹¹

Youth as young as 14 years are permitted to drive farm machinery as employees on others' farms if they receive training and certification in approved tractor and farm machinery certification programs.¹⁰ Furthermore, there is no age or task restriction for youth working on a farm owned or operated by their parents or guardians.¹¹ Therefore, parents (or guardians) can decide when their children (or wards) are ready to begin operating an ATV and to what extent these youth will be involved in ATV work while working on land owned or operated by their parents or guardians.¹²

Youth ATV operators in the agricultural industry

One of the most common causes of fatal and nonfatal farm injuries among youth in agricultural settings is farm machinery.¹ ATVs are commonly used in agricultural operations to apply fertilizer and chemicals, inspect livestock and crops, supervise workers, transport personnel and material, mow grass, round up livestock, and carry and tow implements.^{13,14} ATVs are reported as the primary source of vehicle injury for youth on farms, causing 63% of vehicle-related injuries.^{15,16} Despite efforts to prevent childhood injuries through engineering controls, administrative controls, application of PPE, and training, the number of ATV-related injuries among farm youth has increased 150% in recent years.^{3,17} And more broadly, beyond agriculture, there are over 24,000 estimated ATV-related injuries annually among youth younger than 16 years-of-age.¹⁸

Youth perform a wide range of tasks on farms, including operating farm machinery like tractors and ATVs. Due to physical limitations in strength and anthropometric dimensions, some work tasks could be riskier for youth than adults, thus increasing their likelihood of being injured or even killed. Several studies have shown a strong relationship between the injuries of youth and their ages, anthropometric characteristics, and

developmental abilities.^{19–21} For example, the results of previous studies showed that youth younger than 16 are not capable of safely operating tractors^{22–24} or ATVs.²⁵

Different recommendations exist regarding the minimum age, required physical and mental capabilities, and safety requirements for ATV operation. Those recommendations are inconsistent and may be affected by variances in state law. Also, to our knowledge, none of the reviewed recommendations are evidence-based due to a lack of quantitative and systematic information about the extent of the physical and mental mismatches between requirements for operating ATVs and youth's capabilities. The lack of clear and consistent information may mislead young ATV riders and their parents, thus increasing the risk of injury to young operators.

This study aimed to review the available ATV standards, recommendations, guidelines, regulations, and studies related to age limitations, physical and mental capabilities, safety requirements, and injuries and fatalities of youth riding ATVs on the farm. The main goal of this study is to identify the research voids and propose changes to improve current ATV guidelines. Results of this study will contribute to the scientific basis for developing regulatory and advisory guidelines for youth operating ATVs on farms.^{26–29}

Materials and Methods

We conducted a systematic review³⁰ of the literature and identified relevant articles, guidelines, standards, state laws, and recommendations on age limitations, physical and mental capabilities, safety requirements, and injuries and fatalities of children riding ATVs on farms. The literature review procedures included: (1) conducting a literature search, (2) selection of relevant sources using inclusion and exclusion criteria, (3) extracting information from each source, and (4) consolidation of the results.

The search was conducted through Google and Google Scholar in English for recent documents (after 1990). These two search engines include different types of sources, such as conference proceedings, books, reports, guidelines, and standards. Also, Google Scholar can search the full text of

articles rather than just the citation, abstract, and tagging information in the PubMed and Web of Science search. Five separate searches were performed to incorporate age limitations, physical and mental capabilities, safety requirements, and injuries and fatalities of youth riding ATVs on farms. The search terms included:

1. ATV OR all terrain vehicle OR all-terrain vehicle OR quad-bike OR quad bike OR four-wheeler OR four wheeler AND farm OR ranch OR agricultural OR agriculture AND maturity OR capabilities OR old OR years OR age OR limit AND children OR adolescent OR youth OR kid.
2. ATV OR all terrain vehicle OR all-terrain vehicle OR quad-bike OR quad bike OR four-wheeler OR four wheeler AND farm OR ranch OR agricultural OR agriculture AND cognitive maturity OR mental capabilities OR physical capabilities OR mental OR physical OR Cognitive Development OR Perceptual Development OR Physical Development OR anthropometric OR force OR strength OR human body OR field of view OR vision OR percentile OR body size OR weight AND children OR adolescent OR youth OR kid.
3. ATV OR all-terrain vehicle OR all terrain vehicle OR quad-bike OR quad bike OR four-wheeler OR four wheeler AND farm OR ranch OR agricultural OR agriculture AND safety requirements OR rollover bars OR CPD OR Crush protection device OR crush prevention device OR instruction OR schooling OR teaching OR education OR groundwork OR guidance OR safety OR training safety training OR helmet OR goggle OR face shield OR boot OR long Pant OR long sleeve AND children OR adolescent OR youth OR kid.
4. ATV OR all terrain vehicle OR all-terrain vehicle OR quad-bike OR quad bike OR four-wheeler OR four wheeler AND farm OR ranch OR agricultural OR agriculture AND injury OR fatality OR mortality OR accident OR crash OR wreck AND children OR adolescent OR youth OR kid.
5. ATV OR all terrain vehicle OR all-terrain vehicle OR quad-bike OR quad bike OR four-wheeler OR four wheeler AND law OR regulation OR legislation OR code OR constitution AND state name (e.g., Alabama, Alaska, etc.)

The next step was the selection of relevant sources using inclusion and exclusion criteria. Initially, we reviewed the title of the first 60 documents resulting from each search. If the document was a manuscript, we then examined its abstract and conclusion. If the content of either the abstract or conclusion was relevant to the subjects of interest (age limitations, physical and mental capabilities, safety requirements, and injuries and fatalities of youth riding ATVs on farms), the manuscript was selected for further review of the entire manuscript. For the cases in which the document was not a manuscript (e.g., standards, recommendations, guidelines, regulations, laws, media news), we skimmed through the document to assess its content. Content relevance to the topics of interest was evaluated manually and individually by two researchers to establish inter-rater reliability.³⁰ When both researchers agreed on a certain content, the document was further reviewed.

The third step of the review process (information extraction) was performed by searching for specific keywords within each document selected in step 2. For example, for each source found in the search for the required physical and mental capabilities of youth, keywords such as *force*, *anthropometry*, *body size*, *weight*, and *strength* were searched to identify the relevant material. In the last step (consolidation of results), experts in youth and ATV safety reviewed and categorized the relevant information in each document in a table.

Based on our search terms, we retrieved 182 documents from Google Scholar and 1,189 from Google. As expected, some documents were repeated due to the five separate queries in two search engines. After filtering the titles, we identified 649 unique documents. Among those, 115 documents were selected for further review based on the inclusion/exclusion criteria. Our findings are outlined in the next section of this manuscript.

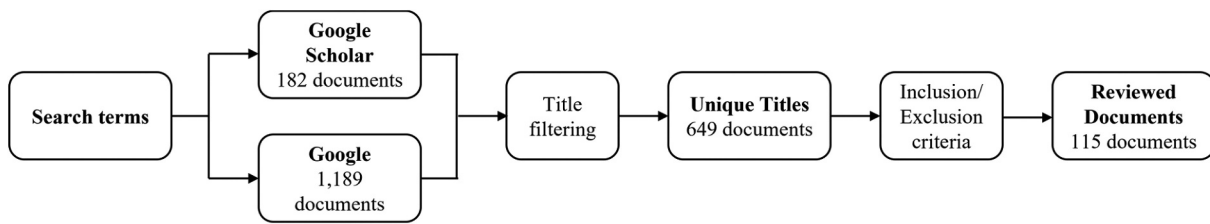


Figure 1. Literature review summary.

A summary of the literature review process is illustrated in [Figure 1](#).

In addition to the initial literature review ([Figure 1](#)), we also evaluated documents that were directly cited by the original 115 selected documents that emerged from our search. For those documents, we repeated steps two (selection of relevant sources using inclusion/exclusion criteria), three (information extraction), and four (consolidation of the results). After filtering the titles, we identified four additional documents.

Results

We have organized the results of our study into four categories: Youth Injuries and Fatalities in ATV Incidents; Age Limitations; Physical and Mental Requirements; and Safety Requirements and PPE.

Youth injuries and fatalities in ATV incidents

Manuscripts we identified that studied injuries and fatalities of youth riding ATVs on farms are summarized in [Table 1](#). Variables that were commonly discussed among all these manuscripts include youths' age, gender, ethnicity, ATV size, the type of activity, incident type, training, and wearing a helmet. It was observed that most ATV incidents involved male youth younger than 16 years old. In addition, in most cases, youth were riding adult-sized ATV models and not wearing a helmet. The most common type of incident was rollover, followed by collisions.

Age limitations

ATVs can weigh up to nearly 1,200 pounds³¹ and reach speeds up to 80 mph.³² The engine size ranges from 50 cc to approximately 1,000 cc for

youth and adult-size ATVs. Controlling heavy, fast, and powerful vehicles require physical and mental capabilities that youth operators may not possess. For this matter, several consensus-derived guidelines, rules, and recommendations have been developed regarding the minimum age for operating ATVs on farms.^{33–40} These guidelines include age limitations for youth to ride utility ATVs (designed for those 16 years-of-age and older) and youth models. Nevertheless, these recommendations are inconsistent and may be affected by laws that vary among states.

The American National Standard Institute/Specialty Vehicle Institute of America (ANSI/SVIA) propose age limitation based on the abilities of children from different age groups and the ATV's maximum speed. Furthermore, based on the medical associations and safety experts' concerns about child safety and health, some have concluded that permitting children younger than 16 years-of-age to operate or ride ATVs could be construed as a form of child neglect or endangerment.⁴¹

According to ANSI/SVIA, youth under the age of 6 should not be allowed to operate ATVs, and youth aged 6–10 should be limited to motorized vehicles that can go no faster than 24 km/h (15 mph) and require constant adult supervision.⁴² Youth between the ages of 11 and 12 can ride ATVs with a maximum speed of 48 km/h (30 mph).⁴²

In the U.S., ATV manufacturing and sales are regulated by the U.S. Consumer Product Safety Commission (CPSC) and not by the U.S. Department of Transportation (DOT). The DOT regulates motor vehicles designed to be used on public roads, and ATVs are not intended for public roadway use. In 2002, nine consumer groups petitioned the CPSC to ban the sales of adult-size ATVs for use by children under the age of 16.⁴³ However, the petition was denied. The CPSC, the

Table 1. Youth injuries and fatalities in ATV incidents.

Authors, (year), title	1- Participants (age) 2- Location 3- Measures and Interventions	Findings
Levenson, M. S., (2003), All-terrain vehicle 2001 injury and exposure studies. ⁹⁹	1- Youth and adults riding ATV (driver and passenger) 2- U.S. 3- Analysis of collected data by CPSC for annual ATV injury report	<ol style="list-style-type: none"> (1) 1997–2001: estimated number of ATV-related injuries treated in E.R.s increased by 104%; the increase includes youth (>16) (2) The two subgroups (>16 and ≤16) do not differ much from each other in the ATV injuries per rider (Driver and passenger) measure (4.6 and 4.8 per thousand riders) risk measure, the year 2001. (3) For each riding hour, the under 16 age group is more likely to be injured than the 16 and over age group (57.6 and 37.4 per million hours). (4) For each driver and driving hour, the under 16 age group is more likely to be injured than the 16 and over age group (10.2 and 6.1 per thousand drivers) and (70.6 and 42.3 per million hours). (5) In 2001, most injuries associated with drivers under the age of 16 occurred with ATVs larger than 90 cc engine size. (6) For each driver and driving hour, the under 16 age group is more likely to be injured than the 16 and over age group driving ATV with engine size larger than 200 ccs (20.2 and 9.5 per thousand drivers) and (109.5 and 59.5 per million hours).
Hendricks. (2005) Injuries to youth living on U.S. farms in 2001 with comparison to 1998. ¹⁰⁰	1- Youth (>20) living on U.S. farms 2- U.S. 3- Telephone survey, CAIS obtained injury surveillance data for youth on farms in collaboration with USDA	<ol style="list-style-type: none"> (1) Although the rate of household youth injuries decreased (not statistically significant) from 1998 to 2001 (18.81/1,000, to 15.71/1,000 household youth), the rate for ATV injuries increased (1.3/1,000 to 1.7/1,000 household youth) (2) Male comprised 65% of 2001 injuries related to ATVs. (3) 2,150 out of the 6,626 estimated injuries associated with transportation in farms were ATV-related. Others include horses, tractors, etc. (4) Estimated 19,397 injuries from a total of 1.2 million youth living in U.S. farms.

(Continued)

Table 1. (Continued).

Hendricks, (2005), Household youth on minority-operated farms in the United States, 2000: Exposures to and injuries from work, horses, ATVs and tractors. ²¹	<p>1- Youth (>20) living on minority-operated U.S. farms</p> <p>2-U.S.</p> <p>3- Telephone survey, obtained nonfatal injury and exposure data from the 2000 Minority Farm Operator Childhood Agricultural Injury Survey (M-CAIS) in collaboration with USDA</p>	<p>(1) Estimated 28,600 youth living in minority operated farms. 17,998 of those were living in Hispanic farms.</p> <p>(2) 26 million youth less than 20 years old live in U.S. farms. Over half of them perform work on the farm.</p> <p>(3) Other racial minority farms (non-Hispanic):</p> <p>(4) Other racial minority farms ATV injury rate: 8.1/1,000 exposed youth</p> <p>(5) 23% of youth drove ATVs (majority males: about 62% vs. 38% females).</p> <p>(6) Total of 348 injuries to youth (<20): 8% were associated with ATV operation (4.5/1,000 exposed youth).</p> <p>(7) 24% of ATV injuries happened to youth (<10)</p> <p>(8) Estimated 24% of all ATV injured household youth were wearing helmets</p> <p>(9) Native American farm ATV injury rate: 6.2/1,000 exposed youth (all males)</p> <p>Hispanic farms:</p> <p>(1) 27% of youth drove an ATV (majority males)</p> <p>(2) 44% of youth injuries happened while working on the farm (14.3/1,000 exposed). Some might have been with ATV.</p> <p>(3) 10% of youth injuries were ATV-related (5.1/1,000 exposed youth). 60% were males vs. 40% females.</p> <p>(4) 48% of ATV youth injured were wearing helmets.</p>
Killingsworth, J. B. (2005). National hospitalization impact of pediatric all-terrain vehicle injuries. ¹⁰¹	<p>1-5292 hospitalized children (<18) due to ATV-related injuries (1997 and 2000)</p> <p>2- U.S.</p> <p>3- Analyses of data based on the 1997 and 2000 Healthcare Cost and Utilization Project Kids' Inpatient Database</p>	<p>(1) Over 2,500 children were hospitalized in 2000 due to ATV-related incidents, a 79% increase from 1997.</p> <p>(2) Approximately 1% of ATV-related hospitalizations resulted in death.</p> <p>(3) The majority (2/3) of pediatric ATV-related injuries involved children who were 14 or less, and approximately 1/5 were less than nine years-of-age.</p>

(Continued)

Table 1. (Continued).

Goldcamp (2006), Nonfatal All-Terrain Vehicle – Related Injuries to Youths Living on Farms in the United States, 2001. ¹²	<p>1- Youth (>20) living on U.S. farms and involved in nonfatal ATV incidents during 2001, 30,744 participants for the 2001 Childhood Agricultural Injury Survey (CAIS) in collaboration with the U.S. Department of Agriculture (USDA).</p> <p>2- U.S.</p> <p>3- A telephone survey</p>	<p>(1) Estimated the ATV ownership and exposure on U.S. farms and an overview of injuries to youths due to ATV use on the farm in 2001.</p> <p>(2) 36% of youths living on farms operated an ATV in 2001</p> <p>(3) Estimated 2,246 nonfatal ATV-related injuries occurred to youths younger than 20 in the U.S. in 2001.</p> <p>(4) 74% of injuries (1,668) occurred to youths members of the household; 69% (1,145) of those were males.</p> <p>(5) 70% of injuries (1,170) involved from 10 to 15 years old.</p> <p>(6) 58% of injuries (970) occurred during recreational activities.</p> <p>(7) 87% of the injuries to household youths occurred on ATVs with engine sizes greater than 200 cc (utility ATVs)</p> <p>(8) Estimated 37% of all ATV injured household youth were wearing helmets</p>
Fleming, S. (2010). All-terrain vehicles: How they are used, crashes, and sales of adult-sized vehicles for children's use. ¹⁰²	<p>1-Several ATV use and crash data</p> <p>2-U.S. Government Accountability Office report on how ATVs are used and the nature, extent, and cost of ATV crashes.</p>	<p>(1) Estimated 816 fatalities and 81,800 injuries treated in E.R.s for ATV accidents in 1999.</p> <p>(2) Between 1999 and 2007 risk of death decreased from 1.4 deaths per 10,000 ATVs used to 1.1 deaths per 10,000 ATVs used.</p> <p>(3) Estimated 534 fatalities and 134,900 injuries treated in E.R.s for ATV accidents in 2007.</p> <p>(4) Between 1999 and 2007, the risk of injury decreased from 193 injuries per 10,000 ATVs used to 129.7 injuries per 10,000 ATVs used.</p> <p>(5) 7/10 sale dealers checked were willing to sell adult-sized ATVs for children use</p> <p>(6) 22% of fatalities between 1999 and 2008 involved children < 16 years old.</p> <p>(7) 94% of children that died in 2005 were riding an adult-sized ATV. For the 2006–2008 period, it was 93%.</p> <p>(8) About one-fifth of the deaths and about one-third of the nonfatal injuries involved children <16 years old.</p> <p>(9) 34% of fatalities from 1999 to 2005 were due to vehicle tripping/flipping.</p>

(Continued)

Table 1. (Continued).

<p>Jennissen CA. (2016), The effect of passengers on all-terrain vehicle crash mechanisms and injuries.²⁵</p>	<p>1-537 ATV-related trauma cases were analyzed (youth and adult). 2-U.S. 3- Performed a retrospective chart review of ATV crash victims at a U.S. Midwest trauma center (2002–2013).</p>	<ol style="list-style-type: none"> (1) 799 deaths in the U.S. due to ATV accidents in 2009. (2) Out of 537 evaluated cases, 20% were passengers or drivers with passengers (3) 77% were males (4) 25% were ≤15 years-of-age (5) 21% wore helmets during an accident (6) Youth (≤15 years old) were significantly more likely to have passengers among youths (29% vs. 10% for >15). (7) Adults (16–25) were more likely to have passengers than adults older than 25 (16% vs. 5%). (8) 50% of passengers were ≤15 years-of-age (9) 71% of non-collision events were rollovers. (10) 10. Back rollovers were 2.5 more likely than rollovers in other directions for cases with passengers. (11) 11. Passengers are 3.6 times more likely to fall or be ejected. (12) 12. 60% of all victims fell off or were ejected. 29% were stuck or pinned by ATV.
--	---	--

industry, and many consumer advocates recommend selling only youth-model ATVs for children.

Nevertheless, there are no ATVs designed/manufactured for children younger than 6. Vehicles for children 6 years-of-age and older have traditionally had engine sizes less than 70 cc, and those for children 12 years-of-age and older have been 90 cc or less. The CPSC recommends that these vehicles be used by children with adult supervision.⁴⁴ Previous recommendations based on engine size by operator’s age are given in Table 2.⁴⁴ In the case of ATVs, the CPSC currently has adopted the 2017 voluntary standard developed by the Specialty Vehicle Institute of America (SVIA) and the American National Standards Institute (ANSI),⁴² which is the most up-to-date standard regarding ATV-youth fit.

Table 2. Age of operator and the ATV engine size, as recommended by the CPSC.⁴⁴

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

The American National Standard for Four Wheel All-Terrain Vehicles⁴² is a “voluntary” standard that provides definitions for youth category ATVs (Y-6+, Y-10+, Y-12+, and T). Based on this standard, the criterion determining age-designated youth labels is the maximum speed of the vehicle. For example, Y-10+ ATV models should only be used by children aged 10 and older. The maximum speed associated with each ATV category is presented in Table 3.

The European standard titled “ATV Safety requirements and test methods”⁴⁵ determined several requirements that ATVs should meet to be commercialized in Europe. This standard categorized youth-ATVs (type I in this standard) into four groups, including, Y-6+, Y-10+, Y-12+, Y-14+ based on the speed limits, similar to the standard from ANSI/SVIA (Table 2). In addition, the European standard suggests that only operators older than 16 should ride adult-sized ATVs (type II in this standard) for utility or recreational purposes.

Despite the recommendations based on age categories, several national and international organizations^{40,41,46} prohibit youth under 16 from riding ATVs of any size (neither adult nor youth models). Moreover, several medical associations in

Table 3. ATV requirements for speed limits for youth-sized ATVs based on ANSI/SVIA standard.

Label	Youth-sized age classification	Maximum limited speed capability-with speed governor in km/h (mph)	Maximum unrestricted speed capability-without a governor in km/h (mph)
Y-6+	Children 6 years old and older	16 (10)	24 (15)
Y-10+	Children 10 years old and older	24 (15)	48 (30)
Y-12+	Children 12 years old and older	24 (15)	48 (30)
T	Children 14 years old and older	32 and 48 (20 and 30)	61 (38)

the U.S., including the AAP⁴⁰ and the ACS,⁴¹ warn that all ATVs are unsafe for youth, and no one under 16 years should ride ATVs at all.⁴⁰ Some also indicate that youth under 12 have neither the required physical capabilities (anthropometry and strength) nor the motor skills to safely handle an ATV. They also indicate that youth under 16 do not possess the cognitive capabilities (perceptual abilities or judgment) required to control high-power motorized vehicles. Lastly, Franklin et al. advocated that the sales of youth-size ATVs should be stopped in Australia for safety reasons.⁴⁶

The laws of all 50 U.S. states regarding ATV riding for youth were reviewed in this study and vary considerably. The most common regulations found in our search involved the following:

- Age limitations for operators
- Required safety equipment (i.e., helmet and eye protection)
- Adult supervision under age 16, while operating on public roadways
- Training (driver's license, safety certificate)
- Vehicle registration
- Maximum speed
- Size of the ATV for youth (the majority of the sources follow the CPSC recommendation – see Table 2)

There are different regulations and laws at the state and federal levels. However, most rules/laws do not pertain to operations on private land. In addition, most laws are exempted if the vehicle is used for agricultural purposes. For instance, operators can ride without a helmet if they are farming in North Carolina or Wisconsin.⁴⁷ In addition, ATVs in Pennsylvania used exclusively for agricultural purposes are classified in the Pennsylvania Vehicle Code as multipurpose agricultural vehicles (MAVs) and are exempt from the Pennsylvania ATV law.^{48,49} None of

the states' regulations address the physical or mental capabilities required to ride the ATVs.⁵⁰

Numerous studies related to youth's age and ATV use have been conducted; two key studies regarding the age of youth's involvement in agricultural activities and age-based patterns in youth ATV riding behaviors are summarized in (Table 4).

Physical and mental requirements

In this section we identified and reviewed the available sources that addressed the physical and mental capabilities required for children to ride ATVs. Four main requirement areas included: strength, anthropometric characteristics, field of vision, and mental maturity. According to the reviewed literature, youth are capable of riding an ATV if they fulfill all four criteria listed below:

- Are strong enough to activate the ATV controls and turn the handlebars from a lock-to-lock position;^{44,45,51–53}
- Have physically grown enough to reach different controls under various riding scenarios (e.g., hands remain on the handlebar when turning it from lock-to-lock position);^{25,44,45,51,52,54–58}
- Have a wide enough field of vision to see ATV controls and perceive the surrounding environment;^{43,51,53,56}
- Are mentally mature enough to make agile and accurate decisions when reacting to different riding situations (e.g., deviating from an obstacle).^{44,55}

Youth's strength and ATV control activation force

The ATV operator should be strong enough to activate the ATV controls, including the throttle

Table 4. Two studies related to youth age for getting involved in agricultural tasks¹⁰³ and riding ATVs.¹⁰⁴

Authors, (year), title	1- Participants (age) 2- Location 3- Measures and Interventions	Findings
Yang, J., et al. (2012). At what age should children engage in agricultural tasks. ¹⁰³	1-Interview with parents from 264 families regarding their children's involvement in agricultural activities and their opinions about appropriate age involvement. 2-USA (Iowa) 3-Comparison between parents' perceived-as-appropriate ages with actual-performance ages for kids engaging in various agricultural activities.	<p>Families with at least one son:</p> <ul style="list-style-type: none"> ● 54.5% reported the youth rode an ATV ● The average age for first ATV ride is 9.8 years ● 53% of boys rode ATV at a younger age than recommended age by NAGCAT (14-years old) <p>Families with at least one daughter:</p> <ul style="list-style-type: none"> ● 37.2% reported the youth rode an ATV ● The average age for first ATV ride is 10.1 years ● 36.1% of girls rode ATV at a younger age than recommended age by NAGCAT <p>Parents perception:</p> <ul style="list-style-type: none"> ● Appropriate age to drive ATV (average): 12.4 years old ● 74.6% reported younger perceived-as-appropriate age for ATV riding than the recommended age by NAGCAT
Jinnah, H. and Z. J. J. o. a. Stoneman (2016). Age-and gender-based patterns in youth all-terrain vehicle (ATV) riding behaviors. ¹⁰⁴	1-180 farm youth between 10 and 19 years-of-age 2-USA (Georgia) 3-Questionnaire interview with farm youth to better understand the relationships and differences in ATV risk and safety behaviors based on age and gender.	<ul style="list-style-type: none"> ● The mean age for the first ATV ride was 7 for boys and 8 for girls. ● 43% of boys started riding ATVs at 6-years old or less, vs. 30% for girls. ● 94% of boys and 91% of girls under 16 have ridden an adult-sized ATV. ● 81% of boys and 76% of girls admitted having ridden at very high speeds. ● 65% of boys and 56% of girls rode ATVs on public roads. ● 59% of boys and 34% of girls have attempted wheelie jumps. ● 9% of boys and 3% of girls attended safety training for ATV ● 96% of boys and 97% of girls have ridden an ATV as passengers. Only 10% of those had a designated passenger seat. ● 89% of boys and 92% girls transported a passenger on ATV. Only 7% had the passenger seat. ● Older boys (>12) were more likely to wear PPE than older girls (61% vs. 35%).

lever, hand gearshift lever, foot gearshift pedal, ignition switch, headlight switch, handlebar, hand brake lever, and foot brake pedal. An operator's inability to consistently activate these critical ATV components could increase the injury risk to operators and bystanders.

Several reviewed documents discussed the required strength to activate different ATV controls. However, most of these documents relied on qualitative criteria

for evaluating the required youth strength.⁵¹⁻⁵³ For instance, the National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS) ATV guidelines state that "*youth should be strong enough to operate the controls without straining and be able to push the ATV off if pinned underneath.*"⁵¹ Furthermore, the ATV Safety Institute (ASI)'s "readiness checklist" recommends that "*youth should have enough strength to*

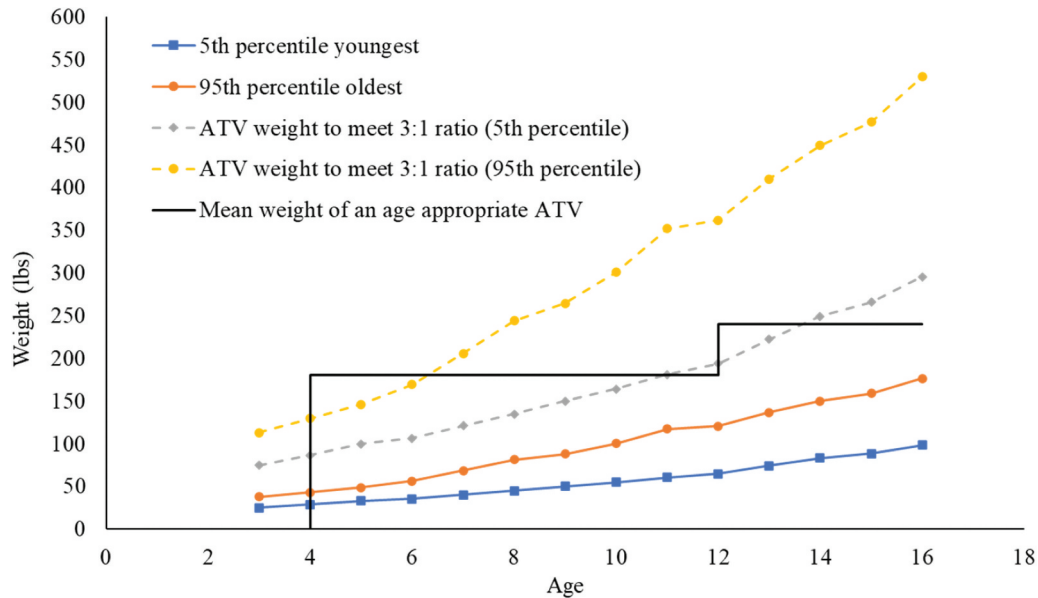


Figure 2. Weight of children and ATVs.⁴⁴

activate the hand controls, shift lever, parking brake, choke and fuel valve, and the brake lever with sufficient pressure.”⁵³ In contrast, the British Standard Institution (BSI), provides quantitative data for actuation forces of some ATV controls.⁴⁵ For example, BSI recommends hand lever brake activation forces between 22 N and 245 N for all adult-sized ATVs.

In an ongoing study, Araujo and Khorsandi (2020) measured the forces required to activate the main ATV controls. The activation forces were then compared to the corresponding strength of youth of various strength percentiles (5th, 50th, and 95th), genders (male and female), and ages (8 to 17).^{28,29} The authors found a significant mismatch between the forces required to operate the ATV controls and the corresponding strength of most youth. The exceptions were males older than 15 years-of-age at the 95th strength percentile.

Furthermore, several study articles and guidelines reviewed in this manuscript recommended that youth should be capable of performing active riding, which refers to the operator moving their pelvis on or off the seat (vertically, laterally, and/or longitudinally) to counterbalance forces while holding the handlebars and keeping both feet on the footrests.^{45,52} Some researchers reported that active riding increased the stability of the ATV and decreased the chance of

a rollover.⁵⁹ However, the capability of performing effective active riding requires that the youth weight be significant compared to the ATV weight. Based on the CPSC, the appropriate child to ATV weight ratio should be 1:3.⁴⁴

Figure 2 shows the weight of the lightest (5th percentile) and heaviest (95th percentile) youth in each age group compared to the mean weight of an age appropriate ATV.⁴⁴ Based on the youth-ATV weight ratio recommended by the CPSC,⁴⁴ 95th percentile kids as young as 7 years old are too heavy for the ATV recommended for their age (<70 cc), and by age 14, most kids are too heavy for ATVs designed for 12–15-year-olds.

Based on the CPSC youth-ATV ratio recommendations (Figure 2), adolescent youth aged 12 to 15 years old might be too tall or heavy for the youth-model ATVs currently on the market and approved by the CPSC.⁴⁴ If a youth is too tall or overweight, their knees may interfere with the handlebars, and they will be unable to control the ATV properly. Moreover, overly tall or heavy youth may significantly raise the center of gravity when on youth-size ATVs, affecting their stability and riding. A higher center of gravity likely increases the probability of the vehicle rolling over, posing a risk of injury or fatality.⁴⁴

Youth's anthropometric characteristics and ATV control reachability

Different standards and organizations have developed recommendations to evaluate youth's ability to effectively reach the ATV's main controls: handlebar, hand brake, foot brake, hand gearshift, foot gearshift, and throttle lever. A summary of youth-fit criteria for ATVs proposed by various organizations^{44,45,51,52,54-58} and a research manuscript²⁵ are shown in [Table 5](#).

In addition to reaching different controls, the European standard⁴⁵ and the N4-HC⁵⁵ suggest evaluating hand reach to hazardous zones on the ATV (e.g., the exhaust, the engine, manifold, etc.). This recommendation is based on another standard (ISO 13857:2008), which determines safety distances required to prevent hazard zones that could burn operators from being touched by upper and lower limbs.⁶⁰

A previous study²⁵ evaluated the fit of one adult-sized ATV and one youth-model ATV for male youth aged 6–15 years old based on 5 of the safety recommendations mentioned in [Table 5](#). The study found that most youth aged 6–15 years did not anthropometrically fit the ATVs based on the fit criteria used. Furthermore, the study suggests that rider age and ATV engine size are poor indicators of youth-ATV fit, and quantitative metrics would improve the assessment of which rider can anthropometrically fit which ATV.

Furthermore, Araujo et al.²⁷ evaluated youths' ability to reach the main controls (i.e., handlebar, hand brake, foot gearshift, throttle lever, on/off switches, and lights) of various ATVs following some of the safety recommendations presented in [Table 5](#).²⁷ The authors developed virtual 3D mock-ups of ATVs and youth and simulated their interaction using an ergonomic software. The study's major finding was that most youth failed to pass at least one of the ATV-youth fit recommendations.

Field of vision

The field of vision of an ATV operator is the visible area they can scan from their seated

position on the vehicle. Many believe that youth operators have a reduced field of vision compared to adults.⁶¹⁻⁶⁴ Youth's limited stature and eye height while seated on an ATV may affect their field of vision.²⁴ Previous studies have shown that a restriction in an operator's field of vision significantly increases the likelihood of a crash and/or loss of control which can lead to rider and bystander injuries.^{65,66} The ATV operator should have a wide field of vision to better access ATV controls, keep the ATV on the path, and detect shapes, sizes, and distances of obstacles. This ensures that the operator can react to unexpected riding situations and make decisions about riding strategies.






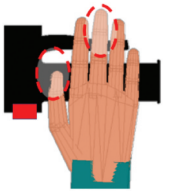


The ASI youth "readiness checklist" includes a section to help parents assess their children's visual perception.⁵⁰ This part of the checklist evaluates youth's capability to see, perceive depth, have adequate peripheral vision, judge the speed of moving objects, estimate the distances of objects (by units such as feet), and follow the movement of objects. The ASI provides some criteria to examine each visual capability.⁵⁶ For example, the ASI determined peripheral or side vision as the ability to see to the sides while looking straight ahead. The ASI provided a method to determine a youth's side vision by looking straight ahead while moving objects to the side. The youth should see objects at 90° to the side while looking straight ahead.⁵³ In addition, based on NCCRAHS guidelines,⁵¹ children should have "good peripheral vision when wearing a helmet."

Mental capabilities

In addition to the youth's physical development, consideration should be given to their mental development. Emotional development or mental maturity includes cognitive, perceptual, focus, discipline, reasoning, and decision-making abilities. A summary of youth's skills and behaviors related to ATV riding are presented in [Tables 6 and 7](#).


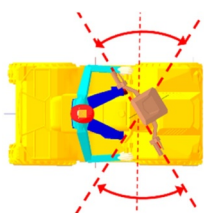

The CPSC determined nine ATV-riding skills and evaluated the capabilities of youth (<16) of different ages to perform these skills. The results are presented in [Table 7](#). The NCCRAHS provided

Table 5. A summary of youth-fit criteria for ATVs proposed by various organizations and a research study.

	Criterion	Reference	Fitting criteria
	Leg and knee clearance	CPSC Bernard et al. (2010)	The recommended vertical distance between the knee and handlebar should be larger than 200 mm. This minimum distance is necessary to ensure the rider can reach the handlebars and steer around an obstacle without the interference of their knees.
	Crotch clearance	CPSC N4-HC FReSH ASI FS4JK ICASH	Crotch clearance is the distance between the crotch and the seat when standing straddling with hands on the handlebar. The crotch clearance should range from 76 mm to 152 mm. This proper clearance ensures youth can stand up and absorb shocks through the legs while riding on rough terrain, minimizes the chance that the seat will hit the operator during a ride, throws the operator over the handlebars, and improves visibility and comfort.
	The angle of lean from vertical	CPSC Bernard et al. (2010)	The proper body size and handlebar height make the driver not need to lean forward more than 30° when standing and grasping the handlebars. If the operator is too tall, the operator should lean forward to reach the handlebar while standing, which increases the chance of ATV tip over.
	Arm reach or Grip reach Leg reach	CPSC N4-HC NCCRAHS ASI ICASH FS4JK	The rider should sit comfortably on the seat and reach all the controls, including sufficient arm length to shift body weight toward the rear and still turn handlebars freely. Operators should have a proper leg length to sit comfortably on the seat and place feet flat on the footrests. This criterion is proposed to ensure the operator can maintain control of the ATV shifting and braking.
	Foot reach or foot brake reach	FS4JK Bernard et al. (2010)	Operators should have a proper foot length to sit comfortably on the seat and place feet flat on the footrests. When the operator places the heel of the shoe against the footrest or in the proper position on the footrests, the toe should be able to depress the footbrake with a simple downward rotation of the foot. The distance from the "ball" of the foot (at the most rearward position in the ATV's footrests) to the brake pedal divided by the length of the foot should be less than 105%. This criterion is proposed to ensure the operator can keep control of the ATV shifting and braking.
	Brake Reach	IPCH N4-HC BSI FReSH ASI FS4JK	With the hand placed in the normal operating position with fingers extended straight out, the first joint from the tip of the middle finger should reach beyond the brake lever. Additionally, the operator's thumb must reach the engine stop switch. This guideline ensures that the operator can adequately stop the ATV.
	Upper leg angle	IPCH N4-HC FS4JK Bernard et al., (2010)	When sitting on the ATV with feet placed on the footrests, the upper portion of the leg should be about horizontal (<math><10^\circ</math>). If the knees are above the hips, the handlebars should be turned in both directions, and the contact with the knees or legs should be checked. This fit criterion is proposed to ensure the operator can control the vehicle.
	Knee angle	IPCH N4-HC Bernard et al., (2010)	When sitting on the ATV with feet placed on the footrests, the knees should bend at least 45 degrees. A knee angle higher than 45° indicates a risk for ineffective foot-brake operation.

(Continued)

Table 5. (Continued).

	Criterion	Reference	Fitting criteria
	Elbow angle	IPCH N4-HC Bernard et al., (2010)	When sitting upright on the ATV and placing hands on the handlebars, not leaning forward, elbows should have a distinct angle between the upper and forearm. If the elbows are at less than right angles (<90°), the operator is too large; if the angle is much more than a right angle (>135°), the operator is too small for the ATV, and steering will be difficult. This guideline is proposed to ensure the operator can steer the ATV and keep it under control.
	Turning Reach and Throttle reach	IPCH N4-HC ASI	The operator should be able to turn the handlebars from lock-to-lock (to the extreme left and right positions) while gripping the handlebars and controlling the throttle and brake levers. This criterion is proposed to ensure the operator can control the speed and steering of the ATV.
	Seat length	CPSC	There should be enough space for the operator to move forward and backward on the seat; a small seat will interfere with active riding.

several recommendations to evaluate the youth's cognitive capabilities before riding ATVs.⁶⁷

The ASI youth "readiness checklist" (the same as mentioned in section 5.3.3 – Field of Vision) includes sections to help parents assess their children's motor development, social/emotional development, and reasoning and decision-making ability.⁵⁶ Based on the checklist, youth should be able to judge the speed of objects, state the distances of objects in terms of standard units, follow the movement of objects, visualize distances as displayed by a picture or photograph, follow a moving object while accomplishing hand manipulation, and maintain relative spans of attention when given a variety of stimuli.⁵⁶

The National 4-H Council⁵⁵ reported that some teenagers, particularly males, experience rapid growth around the age of 13. While they may be physically capable of operating ATVs, they still lack the emotional maturity, judgment, and experience required to operate ATVs safely based on the guidelines related to their mental capabilities.

Safety requirements and PPE

Lack of helmet use^{68–70} and lack of safety gear⁷¹ increase the chance of fatalities and severity of injuries in ATV crashes. This section summarizes the literature concerning crush protection devices (CPDs) and personal protective equipment (PPE), such as helmets, gloves, boots, goggles, face shields, long pants, and long sleeves for youth.

Crush protection devices (CPDs)

CPDs can potentially protect the operator in an ATV rollover incident by absorbing the impact energy and providing a clearance zone under the upside-down ATV. The application of CPDs for farming purposes is recommended in the U.S.⁸² and is mandatory for occupational ATV (a.k.a. quadbike) use in Australia⁷² and Israel.⁷³ Since most rollover incidents on farms happen at low speeds (<25 km/h – 15.5 mph), the NCCRAHS recommends CPD installation specially for youth riding the ATV with speeds less than 48 km/h (30 mph).⁵¹

Table 6. Summary of children's mental development, ATV riding skills, and behaviors.^{105–108.}

Age	Rider Type	Summary	Cognitive stage
0–4	Preliminary passenger	<ul style="list-style-type: none"> The driver's mental capabilities, including the cognitive, perceptual, and motor skills, are not developed sufficiently to allow for driving or riding a motorized vehicle 	Sensorimotor (0–2)
5–7	Rudimentary Driver	<ul style="list-style-type: none"> The driver's mental capabilities, including perceptual, cognitive, and motor abilities, are not developed enough for riding a motorized vehicle. Can perform some activities but only one at a time, i.e., can go but not steer or stop simultaneously. May forget basic safety requirements Can be easily distracted 	Preoperational (2–4)
8–11	Developing Driver	<ul style="list-style-type: none"> Between ages 8 and 9, perceptual and motor skills will be developed enough to be a passenger. Mental capabilities, including operational cognitive skills, are not developed enough to be an ATV driver. Can perform some activities such as go, steer, stop, gears, parking, basic safety Can attempt simple stunt maneuvers (i.e., wheelies) Limited field of vision Some issues in rule remembering Inability to see the future and consequences of actions 	Concrete Operational
12–15	Adept Driver	<ul style="list-style-type: none"> Masters most required riding skills Poor response to unfamiliar situations Adept driver until something goes wrong Lacks judgment of several key factors, such as safe speed and proper terrain for ATV operation Able to see the future and consequences of actions. However, inconsistent in using that ability to make a proper judgment. 	Formal Operational

Table 7. Approximate age when ATV driving skills are acquired.⁴⁴

Age	Rider Type	Start	Go	Steer	Stop	Gears	Park	Safety	Stunts	Error Recovery	
0–4	Primarily Passengers	Some	Some	No	No	No	No	No	No	No	
5–7	Rudimentary	Yes	Yes	Some	Some	No	No	No	No	No	
8–11	Driver Developing	Yes	Yes	Yes	Yes	Yes	Yes	Some	Some	Some	
12–15	Driver, Adept Driver	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Some	Some	
Definitions:		No – This skill is too advanced for most children in this age group					Some – 1) Some children will attempt this skill, and some may seem to master and/or 2) Execution is inconsistent				
		Yes – most children will master this skill									

Training

This section reviews and discusses the available ATV riding and safety training programs in the U.S. In addition to general safety training, specific programs for occupational safety and youth are presented.

In the U.S., the ASI offers a free online ATV “Rider Course” to ATV purchasers. The course is also available for others for a fee. This training is mandatory in several states before riders can ride on public roads or trails.⁵⁰ The ATV Rider Course is available for riders six years or older. Youth riders under the age of 16 years must ride an age-appropriate ATV (Table 1), while trainees 16 years and older may ride an adult-size ATV.⁷⁴ Parents or guardians must attend the course for riders 6–12 years old. The ATV Rider Course takes about 4–6 hours and provides safety education and hands-on riding experience. Based on the ASI’s reports, only about 10% of ATV buyers take the ATV Rider Course.⁷⁵

In addition to the ATV riding course, ATV riders are encouraged to read the vehicle’s manual for proper operation of their machine since ATV models vary in design specifications, such as throttle speed regulators, braking, clutch, and gearshift control. In the U.S., youth as young as 14 have been permitted to ride ATVs while employed on non-family-owned operations if they receive training through an accredited farm machinery safety program.¹⁰ For example, the National Safe Tractor and Machinery Operation Program (NSTMOP) provides training and certification programs for youths.⁷⁶ The NSTMOP’s materials integrate tractor and ATV education, training, and certification. However, these programs lack adequate coverage of specific ATV-related topics such as active riding.

In addition to the ATV riding course, a number of resources are available to learn about ATV operation and riding techniques, including Tips and Practice Guide for the ATV Rider,⁷⁷ ATV

Safety: 4-H Project Leaders Guide,⁷⁸ Utility-Terrain Vehicle Operator Training Course: Instructor’s Guide,⁸ ATV Safety on the Farm (video),⁷⁹ and the ATV Safety Youth Rider Endorsement Program.⁸⁰

Details of two studies that focus on youth training programs including the participants, location, measures and interventions, and key findings are presented in Table 8. In summary, the results indicated that most youth did not get enough training for riding ATVs,⁸¹ and that training can significantly improve youth safety knowledge.⁸²

Discussion

While there is a plethora of guidelines, recommendations, safety training, regulations, and laws, the number of ATV-related incidents among youth is still concerning.¹⁸ Most of the available resources are consensus-based and lack the support of quantitative and systematic scientific evidence. On the other hand, regulations regarding ATV use by youth are subject to variances in state law and can be dismissed if the ATV is operated on private property. The lack of consistency in regulations and guidelines likely confuses the population and may make them recalcitrant towards an attitude of safety.

Youth injuries and fatalities in ATV incidents

Several reasons explain the high number of ATV-related injuries and fatalities among youth in the agricultural sector. Youth are not inclined to wear helmets or other safety gear,^{68–70} and a low percentage participate in ATV training courses. Further, a high rate of youth do not have access to ATV training courses,^{12,81} ride without adult supervision,^{83,84} travel with high speeds,^{68,85} use alcohol and/or drugs,^{68,69,86} ride on paved roads,⁸⁷ and ride at night.^{68,69,83} Moreover, nearly

Table 8. Two studies regarding the availability⁸¹ and importance⁸² of training for youth ATV riders.

Authors, (year), title	1- Participants (age) 2- Location 3- Measures and Interventions	Key Findings
Burgus. (2009) Youths operating all-terrain vehicles – implications for safety education. ⁸¹	1-624 participants in the survey conducted aged 12 to 20 (median 16) 56% were male, and 69% lived on a farm 2- U.S. (Louisville, Kentucky) 3-Administered a survey at a Future Farmers convention to identify safety-related behaviors, injuries, and effects of ATV safety training.	<ol style="list-style-type: none"> (1) The median age when participants started riding ATVs was 9 (2) 24% of participants always wore helmets, 19.5% wore them most of the time, 31% wore them sometimes, 25.5% never wore them. (3) 12% of participants never allowed passengers, 60% allowed it sometimes, 17% allowed it most of the time, 14.1% always allowed it. (4) 18.5% of participants never rode on paved roads, 69% rode on paved roads sometimes, 9.4% rode on paved roads most of the time, 3% always rode on paved roads. (5) 29% of participants have been injured in an ATV incident, 71% have never been injured in an ATV incident. (6) 88% of participants never participated in safety ATV training. Why? <ol style="list-style-type: none"> a. 46% mentioned that training was not available in their area b. 5% did not know about any training c. 4% did not know where the training was held. (1) Among the respondents who were not interested in training, 24% said they did not need training, and 16% said they were already safe riders.
Jennissen. (2015) The safety tips for ATV riders (STARs) program: Short-term impact of a school-based educational intervention. ⁸²	1- Over 4,600 students in 30 Iowa schools participated between November 2010 and April 2013. 2- U.S. (Iowa) 3- Assess the efficacy of the school-based program Safety Tips for ATV Riders (STARs), targeting adolescents.	<p>Pre-program survey:</p> <ol style="list-style-type: none"> 1. 49% of participants were unaware of how many passengers most ATVs can carry. 2. 76% of participants were unaware of the largest ATV size recommended for youth aged 12–15 years. 3. 58% of participants were unaware of when someone can ride an ATV on a public road (according to Iowa law). <p>Post-program</p> <ol style="list-style-type: none"> 4. Only 8% of participants were unaware of how many passengers most ATVs can carry. 5. Only 18% of participants were unaware of the largest ATV size recommended for youth aged 12–15 years. 6. Only 24% of participants were unaware of when someone can ride an ATV on a public road (according to Iowa law). 7. 48% of program attendees were likely or very likely to use the ATV safety info provided. 8. 32% of participants said they were unlikely or very unlikely to use the ATV safety info provided. 9. Females were 42% more likely to use the ATV safety info than males. 10. Students who rode daily/weekly were 69% less likely to use the safety info provided. Students who rode monthly were 46% less likely to use the information. 11. Students who have crashed before were less likely to use the safety info than students that never crashed.

all ATV-related injuries and deaths for youth occur on adult-sized ATVs.^{12,88} This is likely because youth under 16 years-of-age do not have the physical abilities, cognitive maturity, and adequate judgment to safely operate those vehicles.^{33–40}

Age limitations

The CPSC, the industry, and many consumer advocates recommend selling only youth-model ATVs for children,^{42,44,45} despite the viewpoint of some medical associations and international organizations that warn that all ATVs are unsafe for children.^{40,41,46} ATVs have been categorized for various age groups based on ATV engine size and⁴⁴ and maximum riding speed.⁴²

Several sources state that adolescent children (aged 12 to 15) might be very tall or heavy for the youth-model ATVs currently on the market and approved by the CPSC.^{44,55} If a child is very tall or overweight, their knees may interfere with the handlebars (of an youth-model ATV), which would likely affect their ability to manage the ATV.⁴⁴ Also, very tall and/or overweight youth may significantly affect the center of mass on an ATV, thus affecting its stability and making it more prone to roll over.

Riding utility ATVs, which are adult-sized vehicles, is not recommended for youth by several sources. However, some recommendations state youth (<16) can ride utility ATVs on farms after special training.¹⁰ An overview of several recommendations on the age limit for riding ATVs is presented in Table 9.

Physical and mental capabilities

Youth’s strength and ATV control activation force: The available sources regarding the required forces to activate ATV controls and youth strength were

reviewed. There is not enough quantitative information regarding the required actuation forces to activate the ATVs’ controls besides the BSI standard, which provides limited information on activation forces.⁴⁵ There is a need to measure the activation forces of the available ATVs and compare them with the corresponding strength of youth of varying ages and strength percentiles. The ATV actuation forces can be used as criteria for future ATV designs and modifying the currently available designs. In an ongoing project, the ATV activation forces are measured and compared to youth’s corresponding strength.^{28,29}

Youth’s anthropometric characteristic and ATV control reachability: Several documents reviewed in this manuscript recommend youth-fit criteria (Table 4).^{25,44,45,51,52,54–58} Although the available recommendations cover different fitting aspects (i.e., hand and foot reach, arm and leg angle, etc.), those recommendations should be validated with actual riders and ATVs, not only in a virtual environment.²⁷ Araujo et al. (2020) are evaluating the match between the anthropometric dimensions of youth and the dimensions of ATVs based on the recommendations presented in Table 4.

Field of vision: The ASI provided several criteria and practical methods to evaluate one’s visual capabilities. Nevertheless, to the best of our knowledge, no available work has evaluated youth’s field of vision while operating ATVs. There is a need for a study to quantify youth’s field of vision while riding ATVs and compare it with the visual capabilities of an adult counterpart. Furthermore, the influence of external factors such as helmet design on the rider’s field of vision should also be evaluated.

Mental capabilities: Several studies that assessed youth’s mental capabilities for riding ATVs were presented in the manuscript. Although several

Table 9. Summary of available sources regarding the Age limitation for riding utility (adult-sized) ATVs and youth-sized ATVs.

Age limit	Source
Youth (< 6) should not ride an ATV either as driver or passenger	All of the sources that discuss age limitation
Youth (<12) should not ride any ATV	AAOS
Youth (< 16) should not ride any ATV	AAP, ACS, Safe Kids Worldwide
Youth (6–16) can ride child-sized ATVs with some restrictions	ANSI/SVIA, CPSC, BSI
Youth (12–16) should ride only ATVs with an engine size of 90 cc or less and should have limitations on their use of ATVs. In addition, they should be supervised by an adult.	AAOS
Youth (< 16) should not ride utility ATVs, which are adult-sized ATVs, on farms.	NCCRAHS ^{88,96,109}
Youth (< 16) can ride utility ATVs on farms after special training	NSTMOP, BSI

guidelines^{44,56,67} provided criteria for evaluating youth's cognitive capabilities, the guidelines do not offer practical methods to examine each criterion. Moreover, the available guidelines are not comprehensive to assess different aspects of mental capabilities for riding ATVs (e.g., motor skills, attention and focus, reaction time, and decision making under unexpected circumstances). No study evaluated youth's cognitive maturity while riding ATVs. Therefore, additional studies are needed to determine the necessary mental capabilities required for youth to ride ATVs and then to develop tools that can assess youth for these cognitive skills prior to operating ATVs.

Safety requirements

The safety requirements for ATV operation are not consistent among U.S. states. For example, PPE and training for youth are not mandatory in some states, even though they are highly recommended by many sources reviewed in this manuscript. Furthermore, some researchers do not recommend the installation of CPDs,^{89–91} but two NIOSH centers, including the NCCRAHS, recommended installing CPDs on ATVs for farming purposes.^{51,92} The effectiveness of PPE,^{93–95} CPD,^{96–98} and training^{81,82} in preventing incidents and protecting the operator in a potential crash has been widely emphasized in several studies. The authors of this manuscript recommended that youth should only be allowed to ride utility ATVs equipped with a CPD, and after taking safety riding courses. Furthermore, the use of PPE (helmet, gloves, boots, goggles, face shields, long pants, and long sleeves), should be mandatory for youth.

Conclusion

We conducted a systematic review of the literature to identify relevant articles, guidelines, standards, regulations, and recommendations in the field of youth and agricultural ATV safety. This study evaluated different sources regarding the age limitations, physical and mental capabilities, safety requirements, and fatalities and injuries of youth riding ATV.

We identified a need for a guideline including a comprehensive list of evaluation criteria to examine youth's readiness to ride a specific model of ATV. There is also a need for future research to evaluate the required mental capabilities of youth to ride ATVs on farms. Lastly, the application of safety equipment and training should be mandatory in order to enforce their application by operators.

Nomenclature

Abbreviation	Abbreviation	Abbreviation	Abbreviation
All-terrain vehicle	ATV	Hazardous Occupations Orders for Agriculture	AgHOs
American Academy of Orthopedic Surgeons	AAOS	Intermountain Primary Children's Hospital	IPCH
American Academy of Pediatrics	AAP	Iowa's Center for Agricultural Safety and Health	ICASH
American College of Surgeons	ACS	National Children's Center for Rural and Agricultural Health and Safety	NCCRAHS
American National Standards Institute	ANSI	National 4-H Council	N4-HC
ATV Safety Institute	ASI	National Institute for Occupational Safety and Health	NIOSH
British Standard Institution	BSI	National Safe Tractor and Machinery Operation Program	NSTMOP
Computer-Aided Design	CAD	North American Guidelines for Children's Agricultural Tasks	NAGCAT
Consumer Product Safety Commission	CPSC	Occupational Safety and Health Administration	OSHA
Crush Protection device	CPD	Personal Protective Equipment	PPE
Farm and Ranch eXtension in Safety and Health	FReSH	Specialty Vehicle Institute of America	SVIA
Farm Safety for Just Kids	FS4JK	Three-Dimensional	3D

Acknowledgments

The authors would like to acknowledge Bryan Weichelt, Barbara Lee, and Andrea Swenson for reviewing the manuscript and the NCCRAHS and the NIOSH/NIH/CDC for funding the project (Grant No. 5U54 OH009568).

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the National Institute for Occupational Safety and Health [Grant No. 5U54 OH009568].

References

1. NIOSH. *Analyses of the 2014 Childhood Agricultural Injury Survey (CAIS)*. Morgantown, WV: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research; 2016.
2. Bureau of Labor Statistics. *Census of Fatal Occupational Injuries Summary. Fatal Occupational Injuries Counts and Rates by Selected Industries*. Washington, D.C.: U.S. Bureau of Labor Statistics; 2016-17.
3. Wright S, Marlenga B, Lee BC. Childhood agricultural injuries: an update for clinicians. *Curr Probl Pediatr Adolesc Health Care*. 2013;43(2):20–44. doi:10.1016/j.cpped.2012.08.002.
4. Goldcamp M, Hendricks KJ, Myers JR. Farm fatalities to youth 1995–2000: a comparison by age groups. *J Safety Res*. 2004;35(2):151–157. doi:10.1016/j.jsr.2003.11.005.
5. Sterner S. Farm injuries: how can the family farm be made a safer place? *Postgrad Med*. 1991;90(2):141–150. doi:10.1080/00325481.1991.11701013.
6. Wilk VA. Health hazards to children in agriculture. *Am J Ind Med*. 1993;24(3):283–290. doi:10.1002/ajim.4700240305.
7. OSHA. *Enforcement Exemptions and Limitations under the Appropriations Act*. Washington, DC: United States Department of Labor, Occupational Safety and Health Administration; 1998.
8. U.S. Department of Commerce. *Census of Agriculture*. https://www.nass.usda.gov/Publications/AgCensus/2012/Full_Report/Volume_1,_Chapter_1_US/. Accessed November 17, 2021.
9. US Department of Labor. *All about OSHA*, OSHA 3302–06N. Washington, DC: OSHA; 2006.
10. Garvey PM, Murphy DJ, Yoder AM, Hilton JW. National safe tractor and machinery operation program: development and content evaluation. *J Agric Saf Health*. 2008;14(3):333–349. doi:10.13031/2013.24567.
11. DeRoo LA, Rautiainen RH. A systematic review of farm safety interventions. *Am J Prev Med*. 2000;18(4):51–62. doi:10.1016/S0749-3797(00)00141-0.
12. Goldcamp EM, Myers J, Hendricks K, Layne L, Helmkamp J. Nonfatal All-Terrain Vehicle-Related Injuries to Youths Living on Farms in the United States, 2001. *J Rural Health*. 2006;22(4):308–313. doi:10.1111/j.1748-0361.2006.00051.x.
13. Fragar L, Pollock K, Temperley J. A national strategy for improving ATV safety on Australian farms: a Farmsafe Australia program: a report for the rural industries research and development corporation. Rural Ind Res Dev Corporation. 2005.
14. Moore D, Bentley T. All-terrain vehicle-related accident compensation corporation claims in New Zealand 2000/01: a descriptive analysis. *J Occupat Health Safe Aust N Zeal*. 2004;20:335–344.
15. Hendricks K, Goldcamp E. Injury surveillance for youth on farms in the US, 2006. *J Agric Saf Health*. 2010;16(4):279–291. doi:10.13031/2013.34838.
16. Weichert B, SJIp G. Supplemental surveillance: a review of 2015 and 2016 agricultural injury data from news reports on Ag Injury News. *org*. 2019;25:228–235.
17. Bowman SM, Aitken ME, Van Ee CA. Still unsafe, still in use: ongoing epidemic of all-terrain vehicle injury hospitalizations among children. *J Trauma Acute Care Surg*. 2010;69(6):1344–1349. doi:10.1097/TA.0b013e3181ea283d.
18. Topping J *2017 Annual Report of ATV-Related Deaths and Injuries*. 2019.
19. Hard DL, Myers JR. Fatal work-related injuries in the agriculture production sector among youth in the United States, 1992–2002. *J Agromedicine*. 2006;11(2):57–65. doi:10.1300/J096v11n02_09.
20. Brison RJ, Pickett W, Berg RL, Linneman J, Zentner J, Marlenga B. Fatal agricultural injuries in preschool children: risks, injury patterns and strategies for prevention. *Can Med Assoc J*. 2006;174(12):1723–1726. doi:10.1503/cmaj.050857.
21. Hendricks KJ, Myers JR, Layne LA, Goldcamp EM. Household youth on minority operated farms in the United States, 2000: exposures to and injuries from work, horses, ATVs and tractors. *J Safety Res*. 2005;36(2):149–157. doi:10.1016/j.jsr.2005.01.002.
22. Fathallah F, Chang J, Pickett W, Marlenga B. Ability of youth operators to reach farm tractor controls. *Ergonomics*. 2009;52(6):685–694. doi:10.1080/00140130802524641.
23. Fathallah F, Chang J-H, Berg R, Pickett W, Marlenga B. Forces required to operate controls on farm tractors: implications for young operators. *Ergonomics*. 2008;51(7):1096–1108. doi:10.1080/00140130801961901.
24. Chang J, Fathallah F, Pickett W, Miller B, Marlenga B. Limitations in fields of vision for simulated young farm tractor operators. *Ergonomics*. 2010;53(6):758–766. doi:10.1080/00140131003671983.
25. Bernard AC, Mullineaux DR, Auxier JT, Forman JL, Shapiro R, Pienkowski D. Pediatric anthropometrics are inconsistent with current guidelines for assessing rider fit on all-terrain vehicles. *Accid Anal Prev*. 2010;42(4):1220–1225. doi:10.1016/j.aap.2010.01.015.
26. White DJ, Bryant W, Lane J Oregon ATV safety youth rider endorsement program rider guide. <http://www>.

- oregonatvsafety.com/documents/atvriderguide.pdf. Accessed June 15, 2022.
27. Araujo GDM, Khorsandi F, Kabakibo S, Kreylos O. Can youth reach agricultural All-Terrain Vehicle Controls? 2021 ASABE Annual International Virtual Meeting; 2021. doi:10.13031/aim.202100047.
 28. Araujo GDM, Khorsandi F, Abdullah A. Ability of youth to activate agricultural All-Terrain Vehicles' Main Controls. 2020 ASABE Annual International Virtual Meeting; 2020. doi:10.13031/aim.202000598.
 29. Araujo GDM, Khorsandi F. Ability of Youth Operators to Activate Agricultural All-Terrain Vehicles Controls. *Amer Soc Agri Biological Engi.* 2020;1.
 30. Uman LS. Systematic reviews and meta-analyses. *J Canadian Acad Child Adolescent Psychi.* 2011;20(1):57.
 31. Media K. Average weight of different ATV types (with chart). Accessed Jan 18, 2022, <https://boostatv.com/atv-weight/>
 32. Murphy N, Yanchar NL. Yet more pediatric injuries associated with all-terrain vehicles: should kids be using them? *J Trauma Acute Care Surg.* 2004;56(6):1185–1190. doi:10.1097/01.TA.0000123038.94864.E2.
 33. Murphy D, Harshman W ATVs and youth: matching children and vehicles. <https://extension.psu.edu/atvs-and-youth-matching-children-and-vehicles>. Accessed January 18, 2022.
 34. American Academy of Pediatrics. ATVs are dangerous to children: new data demonstrates continued risk of injury and death. <https://www.aap.org/en-us/about-the-aap/aap-press-room/Pages/ATVDataCPSC.aspx>. Accessed July 1, 2022.
 35. Shults RA, Wiles SD, Vajani M, Helmkamp JC. All-terrain vehicle-related nonfatal injuries among young riders: United States, 2001–2003. *Pediatrics.* 2005;116(5):e608–e612. doi:10.1542/peds.2005-0937.
 36. Dolan MA, Knapp JF, Andres J. Three-wheel and four-wheel all-terrain vehicle injuries in children. *Pediatrics.* 1989;84(4):694–698. doi:10.1542/peds.84.4.694.
 37. Anson K, Segedin E, Jones P. ATV (quad bike) injuries in New Zealand children: their extent and severity. *Clin Correspond.* 2009;122(1302):11–28.
 38. Mattei TA, Bond BJ, Hafner JW, et al. Definition and measurement of rider-intrinsic physical attributes influencing all-terrain vehicle safety. *Neurosurg Focus.* 2011;31(5):E6. doi:10.3171/2011.9.FOCUS11176.
 39. Scott A, Dansey R, Hamill J. Dangerous toys. *ANZ J Surg.* 2011;81(3):172–175. doi:10.1111/j.1445-2197.2010.05484.x.
 40. Burd R. American pediatric surgical association trauma committee position statement on the use of all-terrain vehicles by children and youth. *Journal of Pediatric Surgery.* 2009;44(8):1638–1639. doi:10.1016/j.jpedsurg.2009.03.026.
 41. Greenberg BS, Shah CC. All-terrain vehicle use by children: a form of child neglect? *Pediatr Radiol.* 2009;39(7):657–658. doi:10.1007/s00247-009-1258-x.
 42. ANSI/SVIA. *American National Standard for Four Wheel All-terrain Vehicles: Specialty Vehicle Institute of America /American National Standards Institute, ANSI/SVIA 1-2017.* Irvine, CA: Specialty Vehicle Institute of America; 2017.
 43. CPSC. *Petition Requesting Ban of ATV's Sold for the Use of Children under 16 Years of Age, Part 3: Analysis of ATV-Related Fatality Data for CPSC Petition. appendix A: Fit factors for determining proper physical fit of an ATV.* Washington, D.C.: U.S. Consumer Product Safety Commission (CPSC); 2003.
 44. CPSC. Standards for all terrain vehicles and ban of three-wheeled all terrain vehicles; notice of proposed rulemaking. *US Consumer Prod Safety Comm Federal Reg.* 2006;71(154): 45904–45962.
 45. British Standards Institution. *European Standard, All Terrain Vehicles (Atvs -quads) — Safety Requirements and Test Methods.* BS EN 15997. Brussels, Belgium: European Committee for Standardization; 2011.
 46. Franklin RC, Knight S, Lower TJR, Health R. Mount Isa statement on quad bike safety. 2014;14
 47. Department of Natural Resources. *Wisconsin All-Terrain /Utility Terrain Vehicle Laws.* Madison, WI: Department of Natural Resources; 2021. <https://widnr.widen.net/content/89sozstlmu/pdf/2020-ATV-UTV-Regulations.pdf?u=z%E2%80%A6>. Accessed February 20, 2022.
 48. Pennsylvania General Assembly. *Chapter 77, Snowmobiles and All-Terrain Vehicles.* Pennsylvania General Assembly; 1978.
 49. Murphy DJ, Harshman WC. Safe Use of ATVs in Agriculture. <http://nasdonline.org/1888/d001830/safe-use-of-atvs-in-agriculture.html>. Accessed March 20, 2022.
 50. CPSC. State ATV Information. Accessed Oct 13, 2021, 2021. <https://www.cpsc.gov/Safety-Education/Safety-Education-Centers/ATV-Safety-Information-Center/State-ATV-Information>
 51. NCCRAHS. *Operating an All-Terrain vehicle, can youth do this job safely?* National Children's Center for Rural and Agricultural Health and Safety (NCCRAHS); 2020. <https://www.cultivatesafety.org/safety-guideline/?guideline=21&interact=false>. Accessed March 20, 2022.
 52. Fetzer LM, Jepson D, Murphy DJ, Pate M, Yoder AM. Youth ATV safety. Farm and Ranch eXtension in Safety and Health (FRSH) Community of Practice. Accessed Oct 4, 2021, 2021. <https://ag-safety.extension.org/youth-atv-safety/>
 53. ASI. *ATV Safety Institute Readiness Checklist.* Washington, D.C.: SVIA; <https://svia.org/wp-content/uploads/2017/10/ATV-Safety-Readiness.pdf>. Accessed May 10, 2022.
 54. IPCH. Riding the Right ATV. <https://intermountainhealthcare.org/-/media/files/facilities/pch/atv-right-one-sheet.pdf?la=en>. Accessed March 20, 2022.
 55. National 4-H Council. 4-H ATV safety leader's guide. 2014
 56. Parents ASI. *Youngsters, and All Terrain Vehicles.* Irvine, CA: SVIA; 2018. <https://atvsafety.org/wp->

- content/uploads/2018/03/ASI-Parents-Youngsters-ATV-2018.pdf. Accessed March 20, 2022.
57. Safety For Just Kids F. ATV Safety: background information & activity book. Progressive Agriculture. Accessed Oct 14, 2021, 2021. <https://www.progressiveveag.org/uploads/fs4jk/atv/ATVSafetyBooklet.pdf>
 58. ICASH. Off Highway vehicle reference guide. Iowa department of natural resources. Accessed Oct 14, 2021, 2021. <https://icash.public-health.uiowa.edu/wp-content/uploads/2015/04/2014-Off-Highway-Vehicle-Reference-Guide.pdf>
 59. Lock J Inquest into nine (9) deaths caused by Quad Bike accidents. <https://www.safeworkaustralia.gov.au/system/files/documents/1707/state-coroner-of-qld-quad-bike-deaths-inquest-findings.pdf>. Accessed March 20, 2022.
 60. ISO. 13857. Safety of machinery. Safety distances to prevent hazard zones being reached by upper and lower limbs. *International Organization for Standardization Geneva*. 2008.
 61. David S, Chapman AJ, Foot HC, Sheehy N. Peripheral vision and child pedestrian accidents. *Br J Psychol*. 1986;77(4):433–450. doi:10.1111/j.2044-8295.1986.tb02209.x.
 62. Whiteside JA. Peripheral vision in children and adults. *Child Dev*. 1976;47(1):290–293. doi:10.2307/1128316.
 63. Behboudi H, Moghadam RS, Tiefeh N, Karkan MF. Vision disorders in drivers involved in traffic accidents. *J Ophthalmic Vis Res*. 2017;12(4):451. doi:10.4103/jovr.jovr_169_17.
 64. Huisingh C, McGwin G, Wood J, Owsley C. The driving visual field and a history of motor vehicle collision involvement in older drivers: a population-based examination. *Invest Ophthalmol Vis Sci*. 2015;56(1):132–138. doi:10.1167/iovs.14-15194.
 65. Keltner JL, Johnson CA. Visual function, driving safety, and the elderly. *Ophthalmology*. 1987;94(9):1180–1188. doi:10.1016/S0161-6420(87)33309-3.
 66. Johnson CA, Keltner JL. Incidence of visual field loss in 20,000 eyes and its relationship to driving performance. *Arch Ophthalmol*. 1983;101(3):371–375. doi:10.1001/archophth.1983.01040010371002.
 67. NCCRAHS. Cultivate safety: ag youth work guidelines. national children's center for rural and agricultural health and safety (NCCRAHS). Accessed Nov 17 2019. <https://cultivatesafety.org/>
 68. Lord S, Tator CH, Wells S. Examining Ontario deaths due to all-terrain vehicles, and targets for prevention. *Can J Neurol Sci*. 2010;37(3):343–349. doi:10.1017/S0317167100010234.
 69. Krauss EM, Dyer DM, Laupland KB, Buckley R. Ten years of all-terrain vehicle injury, mortality, and health-care costs. *J Trauma Acute Care Surg*. 2010;69(6):1338–1343. doi:10.1097/TA.0b013e3181fc5e7b.
 70. Balthrop PM, Nyland JA, Roberts CS, Wallace J, Van Zyl R, Barber G. Orthopedic trauma from recreational all-terrain vehicle use in central Kentucky: a 6-year review. *J Trauma Acute Care Surg*. 2007;62(5):1163–1170. doi:10.1097/01.ta.0000229814.08289.9a.
 71. Thepyasuwan N, Wan XT, Davis VJ. All-terrain vehicle injuries at arrowhead regional medical Center (Level II): epidemiology, risks, and outcome. *Am Surg*. 2009;75(10):1004–1008. doi:10.1177/000313480907501031.
 72. Australian Competition & Consumer Commission. Public comment submitted on the November 2017 Quad Bike Safety Issue paper. https://consultation.accc.gov.au/product-safety/quad-bike-safety-investigation/consultation/published_select_respondent. Accessed June 10, 2022.
 73. Israel Ministry of Transport. *Manufacturing and Installation of Safety Farm for Quad Bikes*. Jerusalem, Israel: Israeli Ministry of Transport; 2005.
 74. ATV Safety Institute. New Standards for Youth-Model ATVs. http://www.atv-youth.org/ATVresourcesPage/New_Standards_for_Youth-Model_ATVsfin.pdf. Accessed May 23, 2022.
 75. Neves H, Brazile W, Gilkey DP. ATVs and agriculture: a review of the literature. *ACTA Sci Agric*. 2018;2:178–194.
 76. Murphy D. *National Safe Tractor and Machinery Operations Program: Student Manual. Version 2.20.06*. University Park, PA: National Safe Tractor and Machinery Operation Program; 2020.
 77. ATV Safety Institute. Tips and practice guide for the all-terrain vehicle rider. http://www.atv-youth.org/ATVresourcesPage/Tips_2%20Up_3-20-08_Final.pdf. Accessed June 1, 2022.
 78. The Ohio State University Extension Publications. ATV Safety: 4-H Project Leaders Guide, publication booklet 4-H 555. <https://extensionpubs.osu.edu/atv-safety/>. Accessed December 19 2021.
 79. ATV Safety on the Farm. <http://estore.osu-extension.org>. Accessed June 19, 2022.
 80. Oregon State University Extension Services. 4-H Youth Development: oregon ATV safety, youth rider endorsement program. <http://www.oregonatvsafety.com/>. Accessed December 19, 2021.
 81. Burgus SK, Madsen MD, Sanderson WT, Rautiainen RH. Youths operating all-terrain vehicles —implications for safety education. *J Agromedicine*. 2009;14(2):97–104. doi:10.1080/10599240902751047.
 82. Jennissen CA, Peck J, Wetjen K, Hoogerwerf P, Harland KK, Denning GM. The safety tips for ATV Riders (STARs) programme: short-term impact of a school-based educational intervention. *Inj Prevent*. 2015;21(3):166–172. doi:10.1136/injuryprev-2014-041408.
 83. Hafner JW, Hough SM, Getz MA, Whitehurst Y, Pearl RH. All-terrain vehicle safety and use patterns in central illinois youth. *J Rural Health*. 2010;26(1):67–72. doi:10.1111/j.1748-0361.2009.00267.x.
 84. Campbell BT, Kelliher KM, Borrup K, et al. All-terrain vehicle riding among youth: how do they fair? *J Pediatr Surg*. 2010;45(5):925–929. doi:10.1016/j.jpedsurg.2010.02.021.

85. Sanfilippo JA, Winegar CD, Harrop JS, Albert TJ, Vaccaro AR. All-terrain vehicles and associated spinal injuries. *Spine (Phila Pa 1976)*. 2008;33(18):1982–1985. doi:10.1097/BRS.0b013e31817c7527.
86. Hall AJ, Bixler D, Helmkamp JC, Kraner JC, Kaplan JA. Fatal all-terrain vehicle crashes: injury types and alcohol use. *Am J Prev Med*. 2009;36(4):311–316. doi:10.1016/j.amepre.2008.11.019.
87. Rodgers GB. Factors associated with the all-terrain vehicle mortality rate in the United States: an analysis of state-level data. *Accid Anal Prev*. 2008;40(2):725–732. doi:10.1016/j.aap.2007.09.021.
88. Denning GM, Jennissen CA. Pediatric and adolescent injury in all-terrain vehicles. *Res sport med*. 2018;26(sup1):38–56. doi:10.1080/15438627.2018.1438279.
89. Van Ee CA, Toomey DE, Moroski-Browne BA, Vander Roest M, Wilson A. ATV rollover, rider response, and determinants of injury: in-depth analysis of video-documented ATV rollover events. *Traffic Inj Prev*. 2014;15 Suppl 1(sup1):S190–6. doi:10.1080/15389588.2014.935940.
90. Zellner JW, Kebschull SA, Van Auken RM. *Updated Injury risk/benefit analysis of quadbar crush protection device (CPD) for All-Terrain Vehicles (ATVs)*. Torrance, CA: Dynamic Research Inc.; 2012.
91. Zellner JW, Kebschull SA. *Full-scale dyanmic overturn tests of an ATV with and without a “Quadbar” CPD Using an Injury-monitoring Dummy*. Torrance, CA: Dynamic Research Inc.; 2015.
92. Upper Midwest Agricultural Safety and Health. Farm Safety Check: ATV. <http://umash.umn.edu/farm-safety-check-atv/>. Accessed April 1, 2022.
93. Rostas JW, Donnellan KA, Gonzalez RP, et al. Helmet use is associated with a decrease in intracranial hemorrhage following all-terrain vehicle crashes. *J Trauma Acute Care Surg*. 2014;76(1):201–204. doi:10.1097/TA.0b013e3182a994ff.
94. Merrigan TL, Wall PL, Smith HL, Janus TJ, Sidwell RA. The burden of unhelmeted and uninsured ATV drivers and passengers. *Traffic Inj Prev*. 2011;12(3):251–255. doi:10.1080/15389588.2011.561455.
95. Bethea A, Samanta D, Willis JA, Lucente FC, Chumbe JT. Substance exposure and helmet use in all-terrain vehicle accidents: nine years of experience at a level 1 trauma center. *J Safety Res*. 2016;59:61–67. doi:10.1016/j.jsr.2016.09.006.
96. Grzebieta R, Boufous S, Simmons K, Hicks D, Williamson A, Rechnitzer G. Quad bike and OPD workplace safety survey report: results and conclusions. 2017;
97. Grzebieta R, Rechnitzer G, Simmons K, McIntosh A. Final project summary report: quad bike performance project test results, conclusions, and recommendations. Sydney, NSW: *Transport & Road Safety (TARS)-University of New South Wales*. 2015.
98. Hicks D, Grzebieta R, Boufous S, Rechnitzer G, Robertson D, Simmons K. 147 Effectiveness of operator protection devices to mitigate injuries associated with quad-bike (ATV) rollovers. *Inj Prevent*. 2016;22(Suppl 2):A54. doi:10.1136/injuryprev-2016-042156.147.
99. Levenson MSJW, DC. *US consumer product safety commission. all-terrain vehicle 2001 injury and exposure studies*. Washington, D.C.: U.S. Consumer Product Safety Commission; 2003.
100. Hendricks KJ, Layne LA, Goldcamp EM, JRJJo M. Injuries to youth living on US farms in 2001with comparison to 1998. *J Agromed*. 2005;10(4):19–26. doi:10.1300/J096v10n04_05.
101. Killingsworth JB, Tilford JM, Parker JG, Graham JJ, Dick RM, Aitken ME. National hospitalization impact of pediatric all-terrain vehicle injuries. *Pediatrics*. 2005;115(3):e316–e321. doi:10.1542/peds.2004-1585.
102. Fleming S. *All-terrain Vehicles: How They are Used, Crashes, and Sales of adult-sized Vehicles for Children’s Use*. Washington, D.C.: DIANE Publishing; 2010.
103. Yang J, O’Gara E, Cheng G, et al. At what age should children engage in agricultural tasks? The Journal of rural health: official journal of the American Rural Health Association and the National Rural Health Care Association. 2012;28(4):372–379. doi:10.1111/j.1748-0361.2012.00412.x.
104. Jinnah H, ZJJo S. Age-and gender-based patterns in youth all-terrain vehicle (ATV) riding behaviors. *Journal of Agromedicine*. 2016;21(2):163–170. doi:10.1080/1059924X.2016.1141736.
105. Therrell JA. *AGE DETERMINATION GUIDELINES: relating children’s ages to toy characteristics and play behavior*. Washington, D.C.: U.S. Consumer Product Safety Commission; 2002.
106. Richards MN, Putnick DL, Suwalsky JT, Bornstein MH. Age determination guidelines: relating consumer product characteristics to the skills. Play Behaviors, and Interests of Children. 2020.
107. Branta C, Haubenstricker J, Seefeldt V. Age changes in motor skills during childhood and adolescence. *Exerc Sport Sci Rev*. 1984;12(1):467–520. doi:10.1249/00003677-198401000-00015.
108. Shaffer DR, Kipp K. *Developmental Psychology: Childhood and Adolescence*. Monterey, CA: Cengage Learning; 2013.
109. Hegazy MA, Connor K, Crickmore K, Abdel-Rahim A. The effect of physical maturation on atv head-on collision outcome: a simulation study. Paper prsented at: Transportation Research Board 96th Annual Meeting, 2017-1-8 to 2017-1-12, Washington DC, United States. Paper Number: 17–06116. Accession Number: 01628171.