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Ability of Youth to Activate Agricultural All-Terrain Vehicles' Main Controls

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Ability of Youths Operators to Activate Agricultural All-Terrain Vehicles Controls *(doi:10.13031/aim.202000598)*

ABSTRACT. *All-Terrain Vehicles (ATVs) cause a staggering number of fatalities and injuries among children in rural communities in the United States. For instance, there were 52 fatalities and 26 nonfatal injuries among youths operating ATVs on American farms in 2015. Previous studies indicated that children are more vulnerable to injuries than adults because of their less-developed physical and behavioral characteristics. Particularly, one study demonstrated that youths could only activate a few tractor controls due to their strength limitations. Thus, it has been hypothesized that youths are often involved in ATV crashes because of these limitations concerning the activation forces of ATVs'* controls*. Therefore, it is necessary to evaluate potential discrepancies between youths' strength and the activation forces of Agricultural ATVs' controls. This study aimed to compare children's strength with the forces required to activate the four most used ATV* controls *(foot-brakes, hand-brakes, handlebar, and throttle lever). A button load cell, a handheld force gauge, and a pressure glove were used to measure the activation forces of the ATV controls. In total, 38 utility ATVs and male youths from three age groups (6 – 11, 12 – 15, and 16 – 20 years old) and three strength percentiles (5th, 50th, and 95th) were evaluated. Preliminary results demonstrate a mismatch between the activation forces of ATVs' controls and children's strength. Our findings indicated that children under 16 years old are not strong enough to safely steer the handlebars of 24% of the evaluated ATVs. The inability to steer the handlebar makes it difficult to control the vehicle, thus increasing the risk of crashes. The results were even more striking for small (5th percentile) children under 11 years of age, as 93% of the ATVs presented activation forces above the youth's corresponding strength. These discrepancies compromise the youths' capability to ride the ATVs, which places them at an increased risk of crashes.*

Keywords. *ATV, crashes, ergonomics, incidents, safety, resistance forces, youth.*

Introduction

All-Terrain Vehicles (ATVs) cause a staggering number of fatalities and injuries among children in rural communities in the United States. For instance the news media reported 52 fatalities and 26 nonfatal injuries among youths operating ATVs on American farms between 2015 and 2016 (Weichelt & Gorucu, 2018). The implementation of farming attachments such as sprayers and tillers increased ATVs' popularity in the agricultural setting (Cavallo, Gorucu, & Murphy, 2015). For comparison, youths younger than 16 are now more likely to have used a utility ATV than a tractor (Goldcamp, Myers, Hendricks, Layne, & Helmkamp, 2006). However, the increase in ATVs' power, size, weight, and speed made these vehicles unsafe to be operated by youths.

Previous studies indicated that children are more vulnerable to injuries than adults because of their less-developed physical and behavioral characteristics (Fathallah, Chang, Pickett, & Marlenga, 2009; Pollack-Nelson, Vredenburgh, Zackowitz, Kalsher, & Miller, 2017; Serre et al., 2010; Towner & Mytton, 2009). Particularly, one study demonstrated that youths could only activate a few tractor controls due to limitations in their strength (Fathallah, Chang, Berg, Pickett, & Marlenga, 2008). Although the physical characteristics of youths seem to be an important factor for youth-ATV fit, some of the most common guidelines (ANSI/SVIA, 2017; CPSC, 2006) disregard the rider's physical abilities.

It has been hypothesized that youths are often involved in ATV crashes because of these strength limitations concerning the activation forces of ATVs' controls. However, there is limited quantitative and systematic data comparing children's strength to the activation forces of ATV's controls. Therefore, it is necessary to evaluate potential discrepancies between youths' strength and the activation forces of Agricultural ATVs' controls.

The present study is a continuation of the work presented at the 2020 ASABE International Meeting (De Moura Araujo & Khorsandi, 2020). During the past year, we have evaluated 17 new ATVs and measured the forces required to activate another important ATV control, the throttle lever. Therefore, this manuscript is a progress report of an ongoing study to identify the limitations of youths riding utility ATVs.

The present study aimed to compare children's strength with the forces required to activate the four most used ATV controls (foot-brakes, hand-brakes, handlebar, and throttle lever). The study provides critical evidence that contributes to the scientific basis for modifying regulatory/advisory guidelines and state and national policies for operating utility ATVs.

Material and Methods

Study Overview

This study focused on the activation forces of four ATV controls, including the hand brake lever, foot brake pedal, throttle lever, and handlebar steering. Those controls were selected because they are the most important and frequently used controls in ATVs. In addition, the inability to consistently activate these controls likely places operators and potential bystanders at risk.

Thirty-eight utility ATVs were evaluated in this study. Selected ATVs consisted of vehicles of varying makes, models, sizes, and mileages, from the most common vehicles utilized by American farmworkers (Honda, Yamaha, and Polaris).

Data Collection

The forces required to activate the foot brake pedal were measured in a simulated downhill scenario, as previously described by De Moura Araujo and Khorsandi (2020) (Figure 1a). The data was collected with a button load cell (model 10MR02-500, manufacturer Mark 10, Copiague, NY, USA) attached to the rider's right foot shoe, as shown in Figure 1a.

The forces required to activate both the hand brake lever and the handlebar were measured with a grip pressure sensor glove (GPSG), BT5010 (SENSOR PRODUCTS Inc., Madison, NJ, USA). The pressure data was converted into force measurements by multiplying the pressure values by the total area of the sensors. Hand brake lever's activation forces were collected during a ride on a flat surface at 25 km h^{-1} that is the most common speed at which ATV accidents occur, according to Schalk and Fragar (1999). A line was attached to the ground to indicate the braking point, where the rider should fully press the brake pedal, as shown in Figure 1b.

(a) (b)

Figure 1 – Data collection. (a) Foot brake testing on a downhill scenario. Source: De Moura Araujo and Khorsandi (2020); (b) Hand brake testing

The forces required to steer the handlebar were measured while riding the ATV in a circular path with a radius of 6.7 m at a speed of 25 km h^{-1}, as shown in Figure 2. The radius of 6.7 m was selected based on a previous study's recommendation (Grzebieta et al., 2015). On the other hand, the speed of 25 km h^{-1} was calculated to match the ATV's maximum lateral acceleration prior to rollover (rollover threshold). Tests were conducted in both clockwise and counterclockwise directions.

Lastly, the forces required to activate the throttle lever were measured with a handheld force gauge model 475055 (EXTECH Instruments, Waltham, MA, USA). Continuous and peak force measurements were obtained through an RS-232-to-USB serial connection to a portable computer via custom-built software Extech Data Acquisition 407001A. The device was placed perpendicular to the throttle lever.

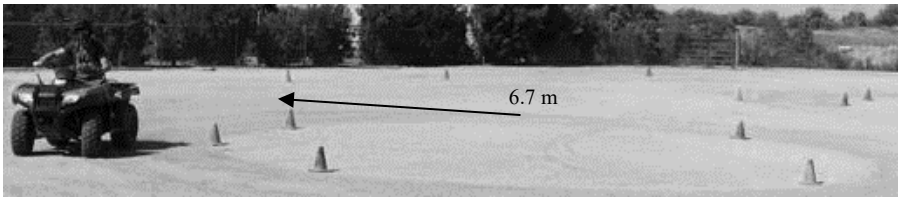

Figure 2 – Handlebar testing in a circular path. Source: De Moura Araujo and Khorsandi (2020)

Youths' Corresponding Strength

The physical strength of youths was retrieved from two public datasets (Department of Trade and Industry, 2000, 2002). Corresponding youth strength to each ATV control is presented in Table 1.

Table 1 - Corresponding youth strength

	Fit Criterion	Corresponding youth strength
1	Foot brake	Press strength with foot pedal
2	Hand brake	Pulling grip (140 mm)
3	Handlebar	Push (cylindrical bar – one-handed strength)
4	Throttle lever	Push with thumb

Data Analysis

The primary results consist of measures of the activation forces required to activate the ATV controls and youths' corresponding strength. This study evaluated male youths aging from 6 to 20 years old, from three percentiles in strength (5th, 50th, and 95th). Force measurements of ATV controls were replicated three for each vehicle. All following analyses comparing activation forces to youths' corresponding strength were based upon the median force for each ATV model, as recommended by Fathallah et al. (2008).

The suitability of ATVs to riders (binary dependent variable) was determined based on potential mismatches (fit criteria) between the activation forces of the ATV controls (independent variable) and youths' strength (independent

variable). In other words, the activation forces of the ATV controls must be smaller than the youth's corresponding strength for an ATV to be considered "suitable to the rider".

Results

In this study, 38 ATV models were evaluated from three manufactures (Honda, Yamaha, and Polaris). Around 30% of the vehicles being assessed were brand new, whereas 88% (n = 23) of the remaining ATVs were classified in either good or excellent condition. Engine capacity range was from 90-700 cc, with most vehicles in the range of 475-700 cc (around 37%). Moreover, the evaluated ATVs had 4 wheel-drive (71%) or 2-wheel drive (29%), rear axle - solid bar (67%) or suspension system (33%), and manual transmission (86%) or automatic transmission (14%).

A summary of descriptive statistics for the commands' findings is presented in Table 2. A wide range of activation forces for almost all controls was observed.

Table 2 – Descriptive statistics for controls' activation forces (N)

Command	Mean (N)	Std (N)	CV (%)	Min (N)	Max (N)
Foot brake	150.9	45.8	30	75.8	257.0
Hand brake	33.9	21.1	62	8.3	82.2
Handlebar	129.8	116.8	90	4.4	376.7
Throttle lever	21.1	15.3	73	4.0	68.4

Std = Standard deviation

The percentage of ATVs with activation forces exceeding youths' corresponding strength is presented in Table 3 and Figure 3. The results demonstrated that the foot brake is the main limiting control for children riding Agricultural ATVs. Moreover, the data showed that all combinations of youth ages and physical strength percentiles could successfully activate the hand brakes of the vehicles evaluated. Furthermore, the data indicated that males under 16 years old (50th percentile) are not strong enough to safely steer the handlebars of at least 8 % of the assessed vehicles. These findings infer that youths younger than 16 years old are likely not able to safely control the ATV, which increases their risk of crashes.

Table 3 – Percentage of observations with activation forces exceeding youths' corresponding strength for different ATV controls

Age group	6-10 years old			11-15 years old			16-20 years old		
Percentile	5th	50th	95th	5th	50th	95th	5th	50th	95th
Foot brake	84%	37%	16%	47%	0%	0%	29%	0%	0%
Hand brake	0%	0%	0%	0%	0%	0%	0%	0%	0%
Handlebar	50%	21%	0%	50%	8%	0%	32%	0%	0%
Throttle lever	3%	0%	0%	3%	0%	0%	0%	0%	0%
Totals	89%	50%	16%	68%	8%	0%	53%	0%	0%

The results were even more striking for small (5th percentile) boys under 11 years of age, as 89% of the ATVs presented activation forces above the youth's corresponding strength. These discrepancies compromise the youths' capability to ride the ATVs, which places them at an increased risk of crashes. Furthermore, there is a clear trend showing that the percentage of ATVs with activation forces exceeding youths' corresponding strength decreases with rider's age. This trend indicates that older riders have theoretically a smaller probability of getting involved in ATV accidents compared to their younger counterparts. Similar findings were also observed by other studies that evaluated the fit of youth for agricultural vehicles (Fathallah et al., 2008; Fathallah et al., 2009).

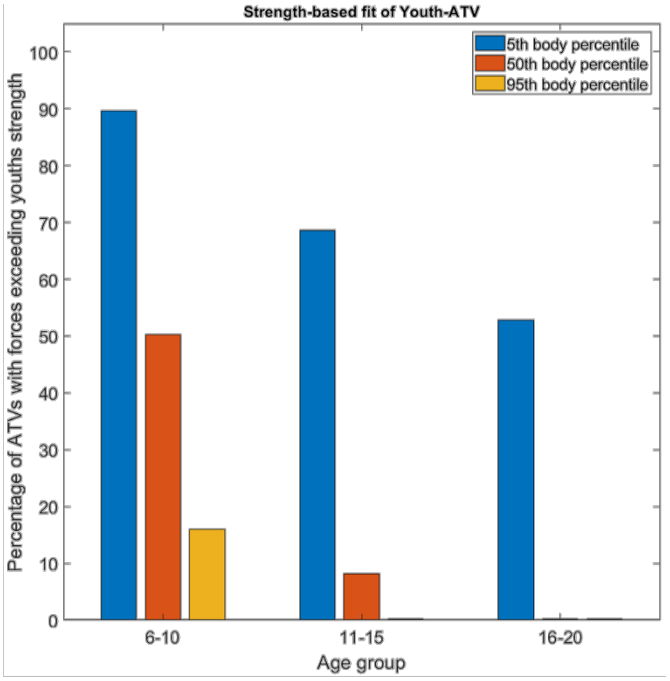

Figure 3 – Percentage of observations with at least one activation force exceeding youths' corresponding strength

Conclusions

This study evaluated the potential discrepancies between youths' strength and the forces required to activate the control of thirty-eight utility ATV models. The main findings were:

- The majority of youths are not capable to activate all controls of utility ATVs;
- The foot brake is the main limiting control for ATV operation;
- The present study provides quantitative and systematic data to support the establishment and refinement of policies and guidelines related to youth-ATV operations to reduce injury events caused by physical mismatches.

Acknowledgment

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