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Ability of Youth Operators to Activate Agricultural All-Terrain Vehicles Controls

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ABSTRACT.
The agricultural community is the largest occupational user of All-Terrain Vehicles (ATVs). The agricultural industry has the highest percentage of ATV-related occupational injuries (59%) and fatalities (65%) among other industries. In addition, several studies showed that youths are involved in 22% of all ATV-related crashes on farms. Moreover, a number of researchers reported a strong relationship between ATV-related injuries of children and their physical, motor, and cognitive skills. Thus, it is hypothesized that youth are involved in ATV-related accidents because they cannot effectively reach or activate the vehicle commands. There is a need to evaluate the mismatches between youth physical capabilities and utility ATVs' operational requirements (e.g., reach distances and resistance forces). This study aimed to evaluate potential discrepancies between the resistance forces of several commands of utility ATVs and the strength of children. A handheld force gauge and a pressure glove were used to measure the activation force of the main commands of utility ATVs. In addition, a novel methodology was developed to measure the forces required to measure the braking forces. The collected data were compared with reported values of children's strength. Preliminary results demonstrate a physical mismatch between ATV operational requirements and children's strength. For example, an average boy under 15 years old was able to comfortably steer the handlebars for only 57% of the evaluated ATVs. The inability of steering the handlebar increases the risk of crashing, since it becomes harder to maneuver the vehicle. The results were even more striking for children under 10 years of age, an average youth was able to push the vehicle away in case of being pinned underneath it for only 33% of the evaluated ATVs. These discrepancies compromise the youth's capability to ride the ATVs, which places them at an increased risk of crashes.

Keywords.
ATV, accidents, children, crashes, ergonomics, resistance forces, youth-ATV fit.

1. Introduction

The implementation of special attachments for farming, such as sprayers and tillers, increased All-Terrain Vehicles' (ATVs) popularity in the agricultural setting (Cavallo, Gorucu, & Murphy, 2015). For instance, children younger than 16 are now more likely to use 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 not safe to be operated by youths. According to Bowman and Aitken (2010) and Wright, Marlenga, and Lee (2013), ATV-related injuries have increased among children in rural households from 1997 and 2006. Moreover, ATV-related hospitalizations increased 139% in the same time (Bowman & Aitken, 2010).

Several guidelines recommend age limitations to restrain ATV use by children; those recommendations are mainly based on vehicle engine size (CPSC, 2006) or speed (ANSI/SVIA, 2017). However, previous studies have shown that age is not an appropriate criterion of ATV-rider fit and further suggested that this assessment should be based on youth's anthropometric dimensions (Bernard et al., 2010). Moreover, a number of researchers demonstrated that children are more vulnerable to injuries than adults due to their physical and physiological characteristics (Fathallah, Chang, Berg, Pickett, & Marlenga, 2008; Fathallah, Chang, Pickett, & Marlenga, 2009; Pollack-Nelson, Vredenburgh, Zackowitz, Kalsher, & Miller, 2017; Serre et al., 2010; Towner & Mytton, 2009). These findings support the argument that youth-ATV fit should consider youth's physical capabilities rather than age or ATV engine size as a factor. Nevertheless, there is no available systematic and quantitative data comparing ATVs' operational requirements and youth's physical capabilities. The lack of such information may increase the risk of injury to young operators as well as bystanders.

It has been hypothesized that many ATV-related injuries occur because children are assigned ATV-related jobs beyond their physical capabilities (American Academy of Pediatrics, 2018; Mattei et al., 2011; Murphy & Harshman, 2014; Scott, Dansey, & Hamill, 2011). This hypothesis has been formulated based on the results of several studies that showed youths are less capable of operating the commands of agricultural vehicles such as ATVs (Bernard et al., 2010) and tractors (Fathallah et al., 2008; Fathallah et al., 2009).

The present study evaluated potential inconsistencies between the operational requirements of utility ATVs (resistance force to activate the main vehicle commands) and the physical capabilities of male youths to fulfill those requirements (corresponding strength). The study provides critical evidence that contributes to the scientific bases for modifying regulatory/advisory guidelines, as well as state and national policies for operating utility ATVs.

2. Material and Methods

2.1 Study Overview

This study focused on the activation forces of the main ATV's commands, including, hand brake, brake pedal, and handlebar steering. Those controls were selected because they are the most important and frequently used controls in agricultural vehicles (Fathallah et al., 2008). In addition, the inability of an operator to consistently activate these components would place operators and potential bystanders at risk.

ATV-rider fit (binary dependent variable) was evaluated based on potential mismatches (fit criteria) between children's strength (independent variable) and the activation forces of the ATV's commands (independent variable). Totally, three fit criteria were evaluated (Hand brakes, foot pedal brake, and handlebar steering). To get a "pass" score, the rider had to succeed in each fit criterion evaluated (i.e., he/she had to be able to exert an activation forcer higher than what was required for that specific command). If the rider failed in a single criterion, the score "fail" was assigned.

Twenty-one 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).

2.2 Activation forces of vehicle commands

According to ATV safety instructor Carina J. Ellis, "the footbrake pedal controls the rear wheels' brake; it is generally activated individually (i.e., without the aid of the hand brakes) when riding downhill, so that the rider can freely use his hands to control the vehicle". Therefore, a downhill scenario was simulated with the aid of a ramp to measure the activation forces of the footbrake, as shown in Figure 1a. ATVs were positioned downhill on the ramp (facing the ground), and the foot brake pedal was completely depressed and then slowly released and pressed again at the moment when the ATV started to roll down the ramp. The data point with the lowest value was identified as the minimum resistance force required for stopping the vehicle. For each ATV, the procedure was repeated three times.

Activation forces on the foot brake were measured with a button load cell model 10MR02-500 (Mark 10, Copiague, NY, USA). The load cell was attached to a shoe and connected to a laptop through a USB serial connection during data collection.

The hand brakes are usually activated for every scenario other than the downhill, being the most common a flat surface. Therefore, the vehicle was accelerated at a speed of 15 mph (most common speed at which ATV accidents occur), on a flat surface of gravel. A specific line (braking point) was set as for the rider to activate the brake to maximum possible capacity until just before the tires started to skid, as shown in Figure 1b.

A grip pressure sensor glove (GPSG), BT5010 (SENSOR PRODUCTS Inc., Madison, NJ, USA) was used to measure the forces required to activate the vehicle hand brakes. The pressure data was converted into force measurements by multiplying the pressure values by the total area of the sensors. Continuous measurements were obtained through a USB serial connection to a portable computer via custom-built software Tactilus 4.1.002rc6.

(a) (b)

Figure 1 - Foot brake testing on a downhill scenario

Activation forces to steer the handlebar were also measured with the grip pressure sensor glove. The vehicle was ridden at a constant speed of 25 km h^{-1} (15 mph) in a circular path with a radius of 6.7 m (25 ft.), as shown in Figure 2. The selected speed was chosen because most ATV accidents occur at or below 25 km h^{-1} (CPSC, 2015; Schalk & Fragar, 1999). Moreover, the radius of 6.7 m was selected based on the recommendation of a previous study (Grzebieta et al., 2015); in conclusion, the combination of selected speed and radius produce lateral accelerations near the vehicle limit (rollover threshold), which decreases the chance of accidents. Tests were conducted in both left and right-hand circle directions and repeated three times in each direction (Grzebieta et al., 2015).

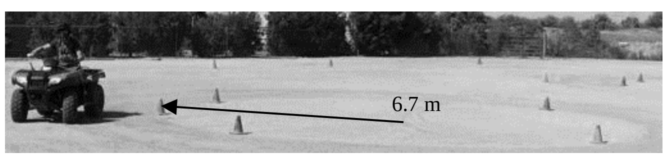

Figure 2 – Handlebar test

2.3 Children's strength

Youth's physical strength and anthropometric data were retrieved from several sources (Department of Trade and Industry, 2000; Owings, Chaffin, Snyder, & Norcutt, 1975; Snyder et al., 1977). Corresponding youth strength to each ATV command 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)

2.4 ATV-rider fit

Potential mismatches between the rider's strength and resistance force of ATV's commands were evaluated by the comparison of means through the F-test. The mean activation force of each control was compared to the mean strength of children of varying group ages, genders, and body sizes (height). A binary score (0 = fail, 1 = pass) was assigned for each potential mismatch evaluated individually. For each ATV, riders were classified as “capable of riding” if his/her cumulative score summed up to 3 (i.e., the rider had successfully passed all tests).

3. Results

In this study, 21 ATV models were evaluated from three manufactures (Honda, Yamaha, and Polaris). Around 50% of the evaluated vehicles were brand new, whereas 82% (n = 9) of the remaining ATVs were classified in either good or excellent condition. Engine capacity range was from 200-700 cc, with most vehicles in the range of 300-475 cc (around 43%), and only a youth ATV (Honda Sportrax 90). Moreover, the evaluated ATVs presented electric power steering (EPS) (66%), 4 wheel-drive (71%), solid suspension (67%), and manual transmission (86%).

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

Table 2 – Descriptive statistics for command activation forces (N)

Command	Mean (N)	Std (N)	CV (%)	Min (N)	Max (N)
Foot brake	179.6 b	52.0	88.7	101.2	278.0
Hand brake	44.9 a	20.4	57.3	11.0	82.2
Handlebar	187.7 b	123.4	55.0	27.5	376.6

Std = Standard deviation; Letters followed by the same letter on the column do not differ statistically by the Tukey test ($\alpha = 0.05$)

The percentage of ATVs in which riders successfully passed all criteria is presented in Figure 3. There is a clear trend showing that the percentage of ATVs accessible to riders (i.e., riders passed all ten criteria) increases along with rider’s age. This 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).

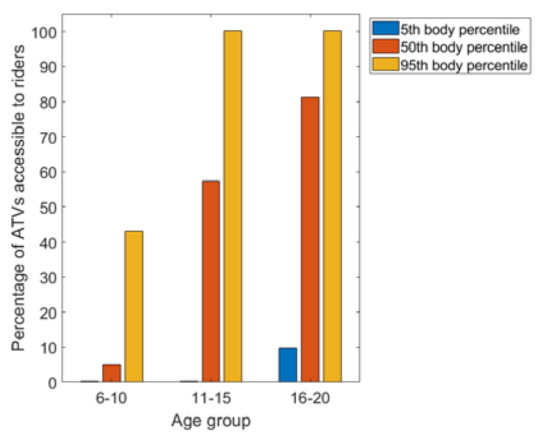

Figure 3 – Percentage of observations (n = 21) for which no mismatches were observed between male children’s corresponding strength and vehicle operational requirements

4. Conclusions

This study evaluated the potential mismatches between youth strength and the required forces to safely operate twenty-one models of ATV. The main findings were: (1) riders’ physical capabilities are potential indicators of youth-ATV fit; (2) younger riders have an increased risk of being involved in incidents, as they are less likely to activate all vehicle’s commands safely.

5. Acknowledgment

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