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ORIGINAL RESEARCH

Perceptions of Tilt Angles of an Agricultural Tractor

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ABSTRACT. A tractor stability simulator has been developed to help study tractor operators' perceptions of angles when the simulator is tilted to the side. The simulator is a trailer-mounted tractor cab equipped with hydraulic lift that can tilt the tractor cabin up to 30 degrees. This paper summarizes data from 82 participants who sat in the simulator while it was tilted. Demographic variables, estimates of tilt angles, and measured tilt angles were collected. The effects of age, gender, tractor driving experience, and frequency of operation on the estimated and measured tilt angles were analyzed. The results showed that about 50% of the participants reported estimations of side tilt angles within ±5 degrees of the actual angles, and nearly the same percentage overestimated the actual side tilt angles. Only a small percentage underestimated the angles. Older, more experienced, and male participants set higher limits on the actual angle at which they felt uncomfortable and would not drive.

KEYWORDS. Agricultural tractor, overturn, rollover, stability, tilt angle

INTRODUCTION

Tractor overturn continues to be a primary area of concern among agricultural safety and health professionals because rollovers continue to be a leading source of injury in agricultural operations.[1] One area of interest to the authors is how an operator's perception of tractor tilt angle may be related to tractor operation decisions on side slopes. To explore this interest, an understanding of potential operator's perceptions of slope angles is important.

The objectives of this study were to

1. increase our understanding of when potential tractor operators become uncomfortable with the degree of tractor tilt and

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when they are so uncomfortable they would not operate a tractor;
2. compare participants' estimated tractor side tilt angles with the measured tilt angles to better understand their perceptions of angles; and
3. explore the effects of age, gender, tractor driving experience, and frequency of tractor usage on participants' estimations of tilt angles.

This is a preliminary study and has some important limitations. The sample size was small and the generalizability of the study is limited by a convenience sample that was not well representative of our population of interest. For example, many participants were not frequent tractor users. Nor were our tests conducted in a realistic tractor operating environment. For these reasons, we cannot draw major conclusions from the data. Even so, our data are useful for beginning to understand how accurate tractor operators may be in estimating tractor tilt angles, and in understanding their perception of risk about operating tractors on different slopes.

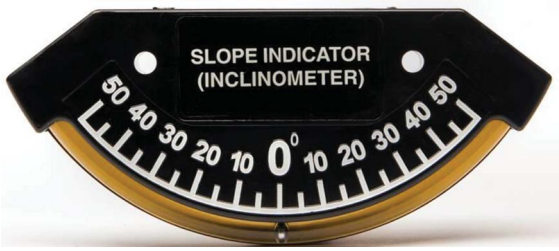
Tractor overturns happen mostly as side rollovers and often occur when the tractor becomes unbalanced while driving across slopes, carrying a load too high, or traveling too fast across uneven ground.[2,3] Small, subtle changes in noise, vibration, ground irregularities, operator fatigue, or loss of attention greatly increase the chance that an operator will miss cues of instability and increase the chance of a rollover.[4] A rollover protective structure (ROPS) in conjunction with a buckled seatbelt protect operators during an overturn.[1] However, many tractors lack ROPS[5] and overturned tractors can result in damage to the tractor and the environment, and can cause considerable downtime and inefficiencies involving important production activities. Educational campaigns encouraging farmers to purchase and install ROPS to prevent tractor overturn injury have been promoted in the USA by tractor manufacturers and dealers.[6] In some countries, such as in most of the states of Australia, ROPS are mandatory, as is a seatbelt if the tractor is fitted with a ROPS and is operated on a public road.[7,8] When using tractors, operators have to be cautious about slopes, speed, field conditions, and distribution of additional masses fitted on the tractor such ballast, towed implements, and trailers.

Discussions surrounding side overturn of tractors often lead to the question, "What is a safe slope?" It is the authors' view that there is no such thing as a "safe" slope. On even mild slopes, such as 10 degrees,[9] a combination of hitting an obstacle with the uphill wheel and a depression with the downhill wheel, or suddenly sliding sideways downhill (such as on wet grass or loose hay) followed by an equally sudden side stop, can result in a rollover. If an implement being pulled by the tractor (e.g., loaded forage wagon) begins to slide, it may trigger an instinctive reaction by the operator that results in the tractor overturning. Additional factors that increase the risk of an overturn on a given slope for one tractor over another include wheel spacing, weighting of the tractor (e.g., a full fuel tank vs. little fuel), position of a load in a front-end loader (if present), tire tread or lack thereof, and operator weight (e.g., a 40-kg youth vs. a 140-kg adult).

Accurate perception of tilt angle seems important in helping tractor drivers to avoid situations that may lead to an overturn, but research suggests that operators are not adept at predicting an overturn because of the number of factors they must track and analyze.[10] Still, the potential instability of a tractor must be perceived before a corrective response may be taken.[11] However, it is difficult for the driver to sense the risk of tractor rollover especially if there is an implement attached to the tractor.[12]

There are commercially available aftermarket devices to help drivers to understand the steepness of a slope (see Figure 1). Little research has been conducted on the effectiveness of these devices. Studies have been conducted on developing more advanced stability monitoring systems. These monitoring systems can be either visual-based or audio-based warning systems.[13] There are advantages to both type of monitoring systems. For visual displays, the operator has to check the display regularly and read and interpret the signal correctly. In audio-based systems, ambient noise around the tractor operator should be taken into account.[10] Whitmire et al. stated that the ideal alerting

FIGURE 1. A commercially available slope indicator.[15]



message should begin with a brief auditory and visual message followed by only a visual message which remains visible until compliance or acknowledgment.[14]

It is questionable, though, how useful warning devices might be for tractor operators. Palkovics et al., citing studies by Glasner and Sparks and Berthelot, states that rollover accidents were classified into four categories: preventable, potentially preventable, nonpreventable, and preventable unknown for semitrailer trucks.[16–18] Their studies showed that only a minority of rollover accidents could have been avoided with a warning device and potentially more could have been avoided with a skilled driver, but half of the rollover accidents they investigated were not preventable by driver action alone. Goldberg and Parthasarathy studied the factors affecting operators' tractor overturn recognition and response.[11] Factors such as fatigue, tractor motion, and the orientation of the tractor operator play a large role in the operator's ability to correctly assess safe operating conditions. These researchers stated that a tractor operator who is laterally traversing a 20-degree slope will not be able to detect a change in angle until the tractor has rolled an additional 5 degrees in either direction. Operators' understanding of tractor roll angles was studied by Tillapaugh et al.[19] The participants were asked to indicate at what angles they had feelings of moderate risk and of extreme risk. The results showed that the difference between the feeling of moderate risk and the feeling of extreme risk was 6 degrees.

MATERIALS AND METHODS

In this study, a convenience sample was obtained by inviting people walking by the tractor stability simulator (TSS) at two rural community fairs in western Pennsylvania and at the annual Ag Progress Days event in central Pennsylvania. The TSS was used at these sites as an educational aid when discussing tractor overturn risks with interested individuals. The TSS was capable of varying the tractor tilt angle experienced by the operator without introducing any other dynamic variables such as speed, noise, or vibration. Potential participants were asked to complete a brief questionnaire before entering the TSS. All interested individuals were allowed to experience the TSS even if they did not wish to participate in the survey. No participant identification information was collected. Participation was limited to individuals 12 years and older.

Tractor Stability Simulator and Operational Procedures

The TSS consists of a trailer-mounted tractor cab equipped with hydraulic lift that allows the cab to be tilted to a side to a maximum of 30 degrees. The tractor cab is an enclosed ROPS cab with seat belt. Participants were required to use the seat belt for their own safety. A slope indicator (Johnson magnetic angle locator; Johnson Level and Tool, Mequon, WI; accuracy is $\pm$½ degree), observable only by the TSS instructor, was attached to the bottom of the cab. Participants were told to pretend they were operating a tractor. The TSS and the procedures used for entry, operation, and exiting were reviewed and approved by Penn State's institutional review board (IRB). Figure 2 is a photo of the tractor stability simulator.

Each participant completed a questionnaire that inquired about their age, gender, years of tractor operation experience, the size of the tractor most often operated, tasks most often done with the tractor, how they learned to operate tractors, and the frequency of tractor usage. Not all participants answered all questions.

Estimation of tilt angle and recording of actual tilt angle for each participant were

FIGURE 2. Tractor stability simulator (TSS).

collected in two stages. In the first stage, the simulator was slowly raised and participants were instructed to verbally indicate when they became uncomfortable about operating a tractor on such a slope but would still continue to operate it. When this stage was reached, the simulator was stopped and the participant was asked at what angle or degree of slope they thought they were at. This angle and the actual angle were recorded. In the second stage, the simulator continued to be raised slowly from the angle where the TSS was stopped for the first stage and the participants were instructed to indicate when they became so uncomfortable about operating a tractor on such a slope that they would definitely not operate the tractor on that slope. This angle and the actual angle were recorded. The participants were then lowered to level and exited the simulator. They then were asked to complete their questionnaire, which asked two evaluative questions about their experience in the TSS.

This procedure resulted in four tilt angle recordings for each participant. These are the dependent variables and are identified and described for data analyses purposes:

a. Reported uncomfortable (RU) angle: the estimated angle that the participant felt uncomfortable with but would still drive the tractor.
b. Measured uncomfortable (MU) angle: the actual slope indicator angle displayed when the participants reported being uncomfortable.
c. Reported would not drive (RWND) angle: the estimated angle at which the participant was so uncomfortable with that he/she would not drive anymore.
d. Measured would not drive (MWND) angle: the actual slope indicator angle at which the participants reported they would not drive anymore.

Data Analysis

Statistical Package for the Social Sciences (SPSS) for Windows Statistical Package was used for statistical analysis.[20] Only data for participants who had valid data for the dependent variables are analyzed and presented in this report. Specifically, the dependent variables are RU, MU, RWND, and MWND. This procedure resulted in a sample size (*N*) of 82. However, not all respondents answered all of the questions on the survey, and consequently the sample size varies for different analyses.

RESULTS

The results are presented as a descriptive analysis of participants in the tractor simulator survey, the outcome of the TSS experience, and the relationship between these two aspects of the investigation.

Characteristics of Participants

The vast majority of the participants were male (82.5%). Age and years of tractor driving experience are shown in Table 1. About 40% of the participants were under 20 years of age, with 22% being 12 to 14 years and 18.3% being 15 to 19 years. At the same time, 29.3% were at least 50 years old. The percentage of respondents with at least 11 years of tractor driving experience was 53.1%, with the bulk (42%) of participants having 21 or more

TABLE 1. Age and Tractor Driving Experience of Participants

Age (years)*	Number (%)	Tractor driving experience (years)	Number (%)
12–14	18 (22.0%)	<1	10 (12.3%)
15–19	15 (18.3%)	1–2	7 (8.6%)
20–29	7 (8.5%)	3–5	11 (13.6%)
30–39	11 (13.4%)	6–10	10 (12.3%)
40–49	7 (8.5%)	11–20	9 (11.1%)
50–59	16 (19.5%)	≥21	34 (42.0%)
≥60	8 (9.8%)		
Total	82 (100.0%)	Total	81 (99.9%)

Note. Some totals do not sum to 100% due to round-off error.
*Age was measured in 5-year intervals and then grouped into the categories shown in Table 1: 12–14, 15–19, 20–24, 25–29, and so on.

years of experience. On the other hand, 20.9% had relatively little experience, 2 years or less of experience (less than 1 year: 12.3%; 1 to 2 years: 8.6%).

Horsepower of Tractors Regularly Operated, Tasks Performed, and Frequency of Tractor Use

The power of the most often operated tractor was asked and the results are shown in Table 2. Fifty-one percent of the participants stated that they operated tractors of 60 horsepower (HP) or less, with most participants (80%) indicating use of tractors with 100 HP or less power. There was no relationship between age and size of tractor (Pearson $r = .155$; $P = .168$).

The participants were also asked the regular tasks most often performed with the tractor (Table 2). The majority of participants (60%) stated that they do brush/grass mowing and other tasks.

The frequency that participants drove tractors is presented in Table 2. Daily tractor use was reported by 15%, and another 15% indicated driving a tractor a few times a week. However, the majority of participants (69%) reported that they drive tractors no more than a few times a month.

TABLE 2. Size of Tractors Regularly Operated, Tasks Performed, and Frequency of Tractor Use

Characteristics	Number (%)
Size (HP)	
Missing	2 (2.5%)
20–60	41 (50.6%)
61–100	24 (29.6%)
≥101	14 (17.3%)
Total	81 (100.0%)
Tasks performed	
Tillage/planting/harvesting/field works	8 (9.8%)
Brush/grass mowing	25 (30.5%)
Brush/grass mowing and other tasks	49 (59.8%)
Total	82 (100.1%)
Use frequency	
Daily	12 (15.4%)
A few times a week	12 (15.4%)
A few times a month	31 (39.7%)
A few times a year	21 (26.9%)
Never	2 (2.6%)
Total	78 (100.0%)

Note. Some totals do not sum to 100% due to round-off error.

Learning to Operate Tractor

Participants were asked how they learned to operate a tractor, and the majority indicated that they learned from their parents (64%); an additional 6.5% indicated learning from their parents and some other source, such as a certification program or another relative (Table 3). The majority of participants in all age groups learned to operate a tractor from their parents, or their parents and some other source (data not shown); differences across age groups did not differ significantly by whether the participant learned from a parent or someone else (Pearson $r = .091$; $P = .430$). Only 3.8% of the participants learned tractor driving from 4-H or Vo-Ag Safe Tractor Operator Certification Program, which is consistent with earlier findings.[21]

TABLE 3. Tractor Operating Learning Methods

Learning method	Number (%)
Parent	50 (64.1%)
Relative	9 (11.5%)
Employer or coworker	2 (2.6%)
4-H or Vo-Ag Safe Tractor Operator Certification Program	3 (3.8%)
Parent and certification program	2 (2.6%)
Parent and relative	2 (2.6%)
Parent, relative, and employer	1 (1.3%)
Other (self, salesmen, etc.)	9 (11.5%)
Total	78 (100.0%)

TABLE 4. Descriptive Statistics for RU, MU, RWND, and MWND Angles (Degrees) ($N = 82$)

Statistic	RU angle	MU angle	RWND angle	MWND angle
Mean	24	12	28	21
Median	20	10	25	20
SD	16	5	13	6
Min	4	4	8	8
Max	70	26	90	30

Tractor Stability Simulator Results

The mean reported uncomfortable (RU) angle was 24 degrees, with a median of 20 degrees; estimations ranged from 4 to 70 degrees (Table 4). The mean and median measured uncomfortable (MU) angles were similar (12 and 10 degrees, respectively); the actual angles ranged from 4 to 26 degrees. The mean reported would not drive (RWND) angle was 28 degrees, with a median of 25 degrees; estimated angles ranged from 8 to 90 degrees. The mean measured would not drive (MWND) angle was 21 degrees, with the median similar at 20 degrees; actual angles ranged from 8 to 30 degrees.

The reported tilt angles (RU, RWND) were found to be significantly higher than the measured tilt angles (MU, MWND), with a mean difference of 8.1 degrees for "uncomfortable" and 4.0 degrees for "would not drive"), respectively (RU − MU: $t = 7.022$, $df = 81$, $P < .001$; RWND − MWND: $t = 5.261$, $df = 81$, $P < .001$; confidence level = 95%).

The differences in reported and measured angles were classified as underestimated, acceptable, and overestimated, as presented in Table 5. The measured angle was subtracted from the reported angle (reported − measured). The limit for an acceptable estimation was set at ±5 degrees of the measured (actual) slope, based on the work of Goldberg and Parthasarathy.[11] Only about 5% of the participants underestimated the angles at which they felt uncomfortable or would not drive (5% and 6%, respectively). Nearly one-half (49%) overestimated the angle at which they felt uncomfortable, with the vast majority (80%) of these participants' estimates being far from the actual angle. Similarly, 43% overestimated the angle at which they would not drive; 51% of these participants' estimates were far from the actual angle.

TABLE 5. Estimations for RU and RWND Angles

Estimation (reported − measured)	Number (%)	
	RU angle	RWND angle
Underestimated (−6 degrees or less)	4 (4.9%)	5 (6.1%)
Acceptable (±5 degrees)	38 (46.3%)	42 (51.2%)
Overestimated (6 degrees or more)	40 (48.8%)	35 (42.7%)
Close (6–10 degrees)	8 (20.0%)	17 (48.6%)
Far (>10 degrees)	32 (80.0%)	18 (51.4%)
Total	82 (100.0%)	82 (100.0%)

The difference between the actual (measured) angles at which participants felt uncomfortable and at which they would not drive was calculated. The mean difference between MU and MWND angles was 8.8 degrees; this represents a statistically significant difference between the measured angle at which participants felt uncomfortable and would not drive ($t = -16.909$; $df = 81$; $P < .001$). Similarly, Tillapaugh et al. (2010) found 6.1 degrees of difference between his participants' feelings of uncomfortable and would not drive.[19] The difference between the reported angles for uncomfortable and would not drive (RU and RWND) is also statistically significant, although not to the extent of the measured angles (Mean RU − RWDD = −3.9; $t = -2.569$; $df = 81$; $P = .012$).

Relationship Between Tractor Stability Simulator Results and Selected Participant Characteristics

The Pearson product-moment correlation coefficient was used to measure the bivariate relationship between the tractor stability results, and age, experience and frequency operating a tractor, and gender (Table 6). Results indicate that frequency was unrelated to the tractor stability results. Although age, gender, and experience were unrelated to the reported angle for uncomfortable and would not drive, all three variables were significantly related to the measured angle for uncomfortable and unwillingness to drive. Results indicate that older participants set higher limits on the actual angle they felt uncomfortable and would not drive ($r = .23$; $P = .040$ and $r = .22$; $P = .043$, respectively). Consistent with the results for age, participants with more experience operating a tractor had higher limits for uncomfortable and would not drive ($r = .29$; $P = .009$ and $r = .32$; $P = .003$, respectively). Also, male participants set higher limits than females on the actual angle they felt uncomfortable and would not drive ($r = -.30$; $P = .007$ and $r = -.26$; $P = .022$, respectively). The results for measured angles are illustrated in Figure 3; it presents the mean measured angles for uncomfortable and would not drive for participants in different age categories, experience categories, and by gender.

TABLE 6. Relationship Between Age, Experience, and Frequency Operating a Tractor, and Gender, and RU, MU, RWND, and MWND Angles: Pearson Product-Moment Correlation Coefficient (*r*)

Characteristic	*n*	*r* (*p* value)			
		RU	MU	RWND	MWND
Age	82	.08 (.489)	.23 (.040)	−.08 (.461)	.22 (.043)
Experience operating a tractor	81	.11 (.347)	.29 (.009)	−.04 (.693)	.32 (.003)
Frequency operating a tractor	78	.18 (.112)	.12 (.280)	.15 (.188)	.19 (.106)
Gender	80	−.03 (.796)	−.30 (.007)	.02 (.884)	−.26 (.022)

FIGURE 3. Mean MU and MWND angles by age, experience operating a tractor, and gender.

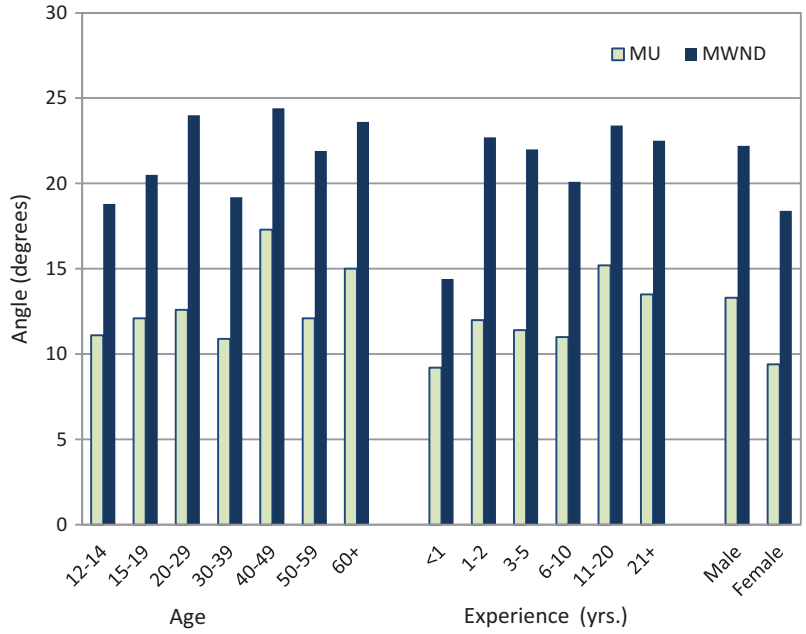


TABLE 7. The Difference Between Reported and Measured Angles for Age and Experience Classes

Characteristic	Mean difference	
	RU − MU	RWND − MWND
Age (years)		
12–14	9.4	5.8
15–19	16.3	12.2
20–29	7.4	4.6
30–39	9.1	10.4
40–49	14.1	10.1
50–59	9.1	1.0
≥60	15.6	1.6
Experience (years)		
<1	8.8	13.5
1–2	6.6	4.9
3–5	18.5	8.6
6–10	13.6	6.9
11–20	7.7	4.7
≥21	11.5	4.5

The mean difference values between reported and measured angles for age and tractor driving experience groups are given in Table 7. It shows that there appears to be no trend in the differences between reported uncomfortable and measured uncomfortable angles but that as age and experience levels increase, the differences between reported and measured angles for would not drive clearly decrease at the higher levels. One possible interpretation of this result may be that older and more experienced operators become more conservative on steeper slopes.

The relationship of years of experience of operating a tractor combined with frequency of tractor driving to the estimated (reported) and measured tilt angles was examined. The combination of years of experience operating a tractor and frequency of tractor driving were distributed as shown in Table 8. The combination of these two variables resulted in four groups:

Group 1: Less experienced and less frequent users (8 participants; 10.4%)
Group 2: Less experienced and more frequent users (9 participants; 11.7%)
Group 3: More experienced and less frequent users (45 participants; 58.4%)
Group 4: More experienced and more frequent users (15 participants; 19.5%)

Analysis of variance (ANOVA) results indicted that that the four groups differed significantly with respect to the MWND angle ($F = 3.232$; $df = 3, 73$; $P = .027$). The Bonferroni adjustment was used to assess the signficance of the mean differences across all pairs of the four groups (1 vs. 2, 1 vs. 3, 1 vs. 4, 2 vs. 3, 2 vs. 4, and 3 vs. 4). Results indicate that Group 3 (more experienced and less frequent users) had a signficantly higher mean on MWND than participants in Group 1 (less experienced and less frequent users ($P = .052$): the means for these two groups on MWND were 23 and 17 degrees, respectively. The means for Groups 2 and 4 fell between these two extremes, and did not differ significantly from either Group 1 or 3. These results indicate that among the infrequent operators, those with more experience had a higher mean MWND

TABLE 8. Distribution of Experience Operating a Tractor Combined With Frequency of Tractor Driving

Experience	Frequency of usage					Total	
	Never	Few/year	Few/month	Few/week	Daily		
≤ 1 year	0	1	4	3	2	10	Less experienced
1–2 years	1	1	1	4	0	7	
3–5 years	0	2	5	2	1	10	More experienced
6–10 years	0	2	4	1	2	9	
11–20 years	0	3	2	0	3	8	
≥21 years	1	11	15	2	4	33	
Total	2	20	31	12	12	77	
		Less frequent users		More frequent users			

angle than those with less experience. However, among more frequent users, having more or less experience was not related to MWND angle. The four groups did not differ signficantly on the other angles ($P > .05$ for RU, MU, and RWND).

DISCUSSION AND SUMMARY

Tractors are the most common agricultural machine, and they are used with a wide range of implements to perform many tasks. While driving the tractor, the operator has to be aware of and attend to many potentially dangerous situations. One of these dangers is the evaluation of the the steepness of slopes the tractor may be travelling across. The drivers' accuraccy at estimating angles is one important component in avoiding side overturns, one of the most common and dangerous types of tractor accidents.

This study investigated the tractor operators' estimates of tilt angles and their level of comfortableness when operating at different lateral tilt angles, and the effects of age, gender, tractor driving experience, and frequency of tractor use on estimations of angles. Because of the small sample size and convenience sampling method, major conclusions cannot be drawn from this data. Data from 82 participants were used in the study. The vast majority of the participants were male; 40% of them were under 20 years old, whereas 29% were 50 or older. Approximately 80% had more than 2 years of experience in tractor driving, and were considered experienced drivers. Eighty percent of the participants operated tractors of 100 HP or less power, and participants reported using tractors mostly (60%) for brush or grass mowing. The majority of participants (69%) were not frequent users, as they reported that they used tractors no more than a few times a month. The measured (actual) uncomfortable and would not drive angles were not significantly related to frequency of tractor usage (daily, weekly, etc.).

A large majority of participants (71%) indicated that they learned how to operate a tractor from their parents, whereas less than 5% indicated they learned to drive a tractor through 4-H or Vo-Ag Safe Tractor Operator Certification Program. This confirms the need to broaden injury prevention initiatives in the agricultural sector, as suggested by Hagel et al.[22]

Participant's age, experience operating a tractor, and gender were significantly related to the measured angle for uncomfortable and would not drive:

- Older participants and participants with more experience set higher limits on the actual angle they felt uncomfortable and would not drive.
- Male participants set higher limits than females on the actual angle they felt uncomfortable and would not drive.
- Older particiants and those with more experience tended to have a smaller difference between the reported and measured angles for which they would not drive.

Older operators and more expereinced operators are often one and the same. Fatality statistics suggest that older male operators often make up a large percent of tractor overturn victims.[1,2] A connection between older/expereinced male operators setting higher limits for operating on slopes is a reasonable supposition.

Forty-nine percent and 42% of the participants overestimated the angle at which they felt uncomfortable and at which they would not drive, respectively. Only a small percentage (5% for RU, 6% for RWND) underestimated the measured angles. The participants began feeling uncomfortable (MU angle) as low as 4 degrees, with an average of 12 degrees, and they stated that they would not drive across a slope (RWND angle) as low as 8 degrees, with an average of 21 degrees. The participants generally overestimated the angle: the mean reported uncomfortable (RU) angle was 24 degrees, while the mean measured uncomfortable angle (MU) was 12 degrees. These data suggest that operators are not very accurate at estimating angles but that the error is in a protective direction. That is, by overestimating the actual angle of the slope, operators would presumably not operate on slopes that are steeper than they think they are on. These data are countered; however, by the data in Table 4 that suggest that the mean

measured angle that participants indicated they would not drive (MWND) was 21 degrees. This exceeds the slope angle at which researchers generally suggest may be hazardous to safely operate tractors.[23,24]

Even a few degrees of increased steepness can result in a tractor rolling over under the certain circumstances, e.g., when a tractor with a raised front-end loader is already on a steep slope and a wheel on the low side drops into a small depression. These few degrees of change may not even be noticed by the operator.[11] It follows, then, that providing operators with real-time slope steepness information as they operate their tractor may help them make better decisions while operating tractors on slopes. Although a ROPS and seat belt offer the best protection from injury from a tractor rollover, it is better to prevent the rollover in the first place. Understanding how tractor operators perceive and understand slopes is one step in this direction.

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