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S Y N O P S I S

Objective. Tractor rollovers are a major cause of farm injuries and fatalities. The authors used data from a statewide surveillance study to estimate the prevalence of safety features such as rollover protective structures, seat belts, and power take-off shields on farm tractors in Kentucky.

Methods. Using data from the Farm Family Health and Hazard Surveillance Project, the authors report on the prevalence of farm tractor safety features by size of farm, by region of the state, by number of tractors per farm, and by tractor age and estimate the prevalence of tractors equipped with rollover protection by region and for the state as a whole.

Results. Of the estimated 85,446 family-owned farms in Kentucky with at least one tractor, an estimated 55.6%, or 47,515 farms, do not have a tractor equipped with a rollover protective structure. Few tractors that are 10 years old or older were found to be equipped with seat belts; no tractors that were more than 20 years old were equipped with seat belts.

Conclusions. Kentucky, with an estimated 25 to 30 tractor-related fatalities each year, may contribute up to 20% of the total number of farm tractor fatalities in the nation. The overall prevalence of rollover protective structures on tractors in Kentucky is lower than estimates for other states as reported in national survey data. The study's findings suggest the need to target smaller farms with one or two tractors for retrofitting of rollover protective structures and for tractor safety programs.

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Among agricultural hazards, the farm tractor has been associated consistently with the greatest number of farm fatalities.¹⁻³ The National Safety Council recently reported an overall tractor fatality rate of 8.2 deaths per 100,000 tractors.³ Farm tractors account for between 150 and 300 deaths annually across the nation, with approximately 50% of these deaths due to overturns.⁴ Tractor overturn has been documented as the most common cause of injury death in the agricultural industry.⁵⁻⁷ One of the goals of *Healthy People 2000* is to reduce the farm worker fatality rate, and focusing attention on the hazards associated with the operation of the farm tractor should help achieve this goal.⁸

Kentucky ranks fourth among the U.S. states in the number of farms.⁹ Eighty-five percent of Kentucky farms are family-owned and operated.¹⁰ Kentucky's terrain, with its steep hills, slopes, and sink holes, may increase the risk of tractor overturns, especially in the eastern portion of the state. Two studies have documented that tractor-related fatalities comprise a substantial percentage of the total agricultural fatalities in the state.^{7,11} Few of the tractors involved in these fatalities were equipped with rollover protective structures (ROPS). With an estimated statewide average of 25 to 30 tractor fatalities each year, Kentucky may contribute as many as 20% of the total annual farm tractor fatalities in the nation.^{4,11}

In addition to fatalities, nonfatal injuries resulting from tractor rollovers, for which limited data exist, are an important concern. Data from a statewide surveillance effort in Kentucky show that there are at least 83 rollovers per year among male Kentucky farmers ages 55 and older, that one out of every nine male farmers ages 55 and older has survived a tractor overturn in his lifetime, and that among those involved in rollovers, one in five report being injured.¹²

Older tractors are less likely to incorporate safety features such as ROPS and seat belts and are more likely to be used in smaller, family-owned farming operations.^{1,13-15} Surveys from several states suggest that the average age of farm tractors is between 15 and 20 years, with many working tractors approaching more than 30 years of age.^{1,4} Lack of safety features can make the tractor a hazardous piece of equipment. In addition to ROPS and seat belts, tractors should be equipped with power take-off (PTO) shields, a safety device designed to offer protection from the PTO stub and the front joint of the drive shaft on machinery such as grain augers and silage blowers, and "slow moving vehicle" signs.

Here, we report on a statewide assessment of the use of farm tractor safety features on family-owned

farms and characterize the high risk farms most in need of interventions.

M E T H O D S

We used data from the Farm Family Health and Hazard Surveillance Project, an effort to describe agricultural risks and injuries among farm families in Kentucky sponsored by the National Institute on Occupational Safety and Health (NIOSH). A farm is defined by the U.S. Census Bureau as any place from which \$1000 or more of agricultural products from livestock, crop, or specialty operations are produced and sold or would normally be sold during a given year.¹⁰ For the present study, we defined single proprietor family farms as farms meeting the U.S. Census definition that are individually or family owned. This definition excludes farms owned as partnerships, by corporations, or by institutions such as governments, universities, or schools.

Sample. The Farm Family Health and Hazard Surveillance Project used two-stage cluster sampling to construct the sampling frame. A brief description follows; further details can be found in an earlier publication.¹⁶

At the first stage, a sample of 60 counties was selected from the 120 Kentucky counties using probability proportional to size sampling, where size was the number of farms in each county based on the 1987 *Census of Agriculture* for Kentucky.¹⁷ Several counties were excluded before sampling, based on logistical considerations such as the likelihood of cooperation from farmers, the availability of telephones, and the low density of farms within the county. The farms in the 60 counties in the survey were found to be representative of the farms in the state as a whole in terms of acreage, employment status of principal operator, and other demographic characteristics of the principal operator.¹⁶

A systematic sample of the single proprietor family farms in each of the 60 counties was selected from a listing maintained by the Kentucky Agricultural Statistics Service.¹⁸ Within each county, the list of farms was ordered by size (acreage) and every *n*th farm was selected to enumerate approximately 125 farms per county. The six counties that contained the largest number of farms were oversampled to obtain the desired sample size for statistical purposes.

Telephone survey. The Farm Hazard and Demographic Enumeration Survey (FHADES) was a short telephone survey conducted from May through Novem-

ber 1994 of 9617 farms from the sample. Survey staff asked farmers about the number of tractors used and the number that were ROPS-equipped. A total of 8271 farms participated in FHADES, for a response rate of 86%. These farms represented 9.3% of the estimated 88,837 eligible, single-proprietor family farms in the state. Here we report the results of the survey for 8086 farms (98% of respondent farms) for which complete data on the variables of interest were available.

To examine regional variation in the distribution of tractor safety features, we used the climatological regions of the state (Eastern, Bluegrass, Central, and Western), estimating farm totals in these regions by summing the county-level estimates of family farms in the counties within each region as reported in the 1992 *Census of Agriculture* for Kentucky.¹⁰ In accordance with traditional survey analysis procedures,^{19,20} we used the percentages calculated from the FHADES data to develop estimates of the number of farms by ROPS status for each of the four regions and for the state as a whole.

We also performed parallel analyses, using the tractor, rather than the farm, as the unit of analysis.

Site visits. Site visits were made from September 1994 through July 1995 to a convenience subsample of 138 of the 8271 farms responding to FHADES.¹⁶ This sub-

sample was selected from farms on which at least one household member was a male age 55 years or older who actively worked on the farm. An industrial hygienist and an agricultural engineer from the University of Kentucky inspected the 259 tractors in use on these farms and recorded information on the make, model, and year of manufacture; the presence or absence of ROPS, seat belts, power take-off shields, and other safety features; and use of the tractor. The site visitors also subjectively assessed whether each tractor was in good condition. We looked at the percentages of tractors with a given safety feature by the age of the tractor.

Data analysis. We used SAS software for the data analyses, calculating confidence intervals for estimates from this complex survey using SUDAAN software.^{21,22} We analyzed data from the convenience sample of farms at which on-site inspections were conducted with simple random sample descriptive statistics using SAS.²¹

RESULTS

Selected characteristics of the 8086 farms, by acreage quartile, are shown in Table 1. A total of 18,113 tractors were reported on these farms, for an estimated mean of 2.3 tractors per farm.

Almost all (96.3%) of the farms in the sample had at

Table 1. Selected characteristics of sampled farms, by acreage quartile, Farm Hazard and Demographic Enumeration Survey, Kentucky, 1995 (N = 8086)

Characteristic	Acreage quartile				All farms
	<60 acres	60-111 acres	112-214 acres	>214 acres	
Number of farms.....	2012	2010	2037	2027	8086
Mean acreage.....	32.3	84.9	159.2	462.8	185.3
Mean age of principal operator.....	53.5	55.8	55.5	54.1	54.7
Mean number of tractors per farm.....	1.5	1.8	2.3	3.4	2.3
Farms without tractors					
Percent.....	8.4	3.4	1.7	1.3	3.7
95% CI.....	7.3,9.5	2.6,4.2	1.2,2.2	0.9,1.7	3.3,4.1
Farms with tractors but without ROPS on any tractor					
Percent.....	75.4	64.6	54.1	30.9	55.6
95% CI.....	73.7,77.1	62.6,66.6	52.0,56.2	28.9,32.8	54.4,56.7

NOTE: Each acreage category represents approximately one-quarter of the farms in the sample.

CI = confidence interval

ROPS = rollover protective structure

Table 2. Percentages of farms by region of state and status of tractor rollover protection, Farm Hazard and Demographic Enumeration Survey, Kentucky, 1995 (N = 8086 farms), and regional and statewide estimates based on these percentages

Variable	Eastern			Bluegrass			Central			Western			All regions		
	Percent	95% CI	Weighted estimate	Percent	95% CI	Weighted estimate	Percent	95% CI	Weighted estimate	Percent	95% CI	Weighted estimate	Percent	95% CI	Weighted estimate
Farms with no tractor	6.8	5.5, 8.1	1071	3.2	2.6,3.7	961	3.3	2.6,4.0	934	2.7	2.0,3.5	425	3.7	3.3,4.1	3391
Farms with one or more tractors	93.2	91.9,94.4	14,565	96.8	96.3,97.4	28,858	96.7	96.0,97.4	27,044	97.3	96.5,98.0	14,979	96.3	95.9,96.7	85,446
No operating tractor equipped with ROPS	58.3	55.6, 61.0	8485	55.5	53.8,57.2	16,014	57.3	55.4,59.2	15,491	50.2	47.8,52.6	7525	55.6	54.5,56.7	47,515
One or more tractors equipped with ROPS	23.9	21.5,26.3	3480	31.9	30.2,33.5	9191	28.4	26.6,30.1	7675	33.5	31.2,35.8	5015	29.7	28.7,30.7	25,361
All operating tractors equipped with ROPS	17.9	15.9,19.8	2600	12.7	11.5,13.8	3653	14.3	12.9, 15.7	3878	16.3	14.5,18.1	2439	14.7	14.0,15.4	12,570
Total farms	—	—	15,636	—	—	29,819	—	—	27,978	—	—	15,404	—	—	88,837

CI = confidence interval
 ROPS = rollover protective structure

least one tractor (Table 2). About half (55.6%; 95% confidence interval [CI] 54.4, 56.7) of the farms with tractors had no tractors equipped with rollover protection.

Based on a total of 88,837 farms in the state,¹⁰ this extrapolates to 47,515 farms without a single tractor equipped with rollover protection (Table 2). Another 29.7% had at least one ROPS-equipped tractor but also had tractors that were not ROPS-equipped. Only 14.7% were reported to have all of their tractors equipped with rollover protection.

The majority (63.0%) of the farms in the sample operated one or two tractors. The tractors on 74.7% (95% CI 73.2, 76.3) of farms with only one tractor were not ROPS-equipped, and neither tractor was ROPS-equipped on 58.2% (CI 56.3, 60.1) of farms with two tractors (Table 3). From these findings, we estimate that there are approximately 37,318 farms in the state, representing 42.0% of all family-operated farms, with either one or two tractors but no ROPS-equipped tractors.

Regional variation. The data suggest modest variation by region of the state with respect to ROPS coverage on farms with tractors. The western portion of the state had the best coverage, with approximately 50.2% of the farms having at least one ROPS-equipped tractor; the eastern portion of the state had the poorest coverage, with 58.3%

of the farms operating tractors without rollover protection (Tables 2 and 3).

Percentages of tractors. We performed additional analysis with tractors, rather than farms, as the unit of analysis (data not shown). Based on these analyses, we calculated that of the estimated 198,007 tractors in use in Kentucky, 29.2% (95% CI 28.6, 29.9), or 57,884 tractors, are ROPS-equipped. Thus 140,123 tractors (70.7% of all tractors) currently used on the 85,446 family-owned and operated farms with tractors are not ROPS-equipped. With the tractor as the unit of analysis, the Bluegrass and Central regions of the state have the lowest percentages of ROPS coverage.

Age of tractors. The Figure shows the distribution by year of tractor manufacture and ROPS status for the 259 tractors inspected on 138 farms. The average age of the tractors inspected was 21.9 years (standard deviation 12.9 years), with a range from one year to 54 years. Nearly one-half (45%) of the tractors inspected were manufactured between 1970 and 1984. Of the 259 tractors examined, 26.6% were ROPS-equipped. None of the tractors manufactured before 1970 were ROPS-equipped. An estimated 93% of the 1990–1995 model tractors were ROPS-equipped, while only 22% of the

tractors manufactured between 1975 and 1979 were ROPS-equipped.

Table 4 shows the distribution of safety features by tractor age categories. Although 79% of the tractors that were 10 years old or newer were equipped with rollover protection, only 32% of the tractors in the 11- to 20-year-old category were ROPS-equipped, and none of the tractors that were more than 20 years old were ROPS-equipped. Few tractors that were more than 10 years old were equipped with seat belts, and none of the tractors older than 20 years were equipped with seat belts. A subjective evaluation of the maintenance and condition of

the tractor, performed by the industrial hygienist and agricultural engineer, found that nearly 91% of the 10-year-old or newer tractors were in good operating condition while 53% of the tractors that were older than 10 years were in good condition. In addition, the majority of older tractors were missing PTO shields and "slow moving vehicle" signs.

DISCUSSION

The results of this study suggest that the large majority of tractors on family-operated farms in Kentucky are

Table 3. Percentage of farms with no ROPS-equipped tractors by region of state and number of tractors per farm, Farm Hazard and Demographic Enumeration Survey, Kentucky 1995 (N = 8086 farms), and regional and statewide estimates based on these percentages

Number of tractors per farm	Eastern region			Bluegrass region			Central region			Western region			All regions		
	Percent	95% CI	Weighted total	Percent	95% CI	Weighted total	Percent	95% CI	Weighted total	Percent	95% CI	Weighted total	Percent	95% CI	Weighted total
0	—	—	1071	—	—	961	—	—	934	—	—	425	—	—	3391
1	72.9	69.4,76.3	6337	73.7	70.8,76.6	7833	76.3	73.6,79.1	9929	74.7	70.9,78.5	4641	74.7	73.2,76.3	28,740
2	55.5	50.8,60.2	5079	61.5	58.5,64.6	9014	58.9	55.5,62.2	8530	52.3	47.8,52.6	4607	58.2	56.3,60.1	27,230
3	34.3	26.7,41.7	1998	48.3	44.6,52.0	6292	40.9	36.2,45.5	4580	37.1	31.7,42.4	2821	42.4	39.9,44.8	15,691
4	39.1	26.2,52.1	677	31.8	27.0,36.6	3077	33.8	27.4,40.1	2202	28.1	21.7,34.5	1484	32.4	29.1,35.7	7440
5	24.2	7.9,40.5	330	33.2	25.9,40.4	1470	14.8	7.6,21.9	1016	10.0	3.4,16.7	753	21.9	17.7,26.2	3569
6	15.1	— ^a	144	16.3	10.0,22.5	1172	16.3	8.2,24.4	787	16.5	8.8,24.2	673	16.3	12.0,20.5	2776
Total	58.3	55.6,61.0	15,636	55.5	53.8,57.2	29,819	57.3	55.4,59.2	27,978	50.2	47.8,52.6	15,404	55.6	54.5,56.7	88,837

^aInsufficient number of cases to calculate interval
CI = confidence interval

Table 4. Safety features and selected characteristics of 259 tractors inspected at 138 on-site farm visits, by age of tractor, Farm Hazard and Demographic Enumeration Survey, Kentucky, 1995

Variable	Age of tractor				All tractors
	≤ 10 years n = 59	11–20 years n = 81	21–30 years n = 51	> 30 years n = 68	
Percent with ROPS	78.6	31.6	0.0	0.0	26.6
Percent with cab	17.9	14.8	3.9	0.0	9.4
Percent with power take-off shield	57.1	26.3	28.0	15.2	30.6
Percent with seat belt	78.6	21.3	0.0	0.0	24.0
Percent with "slow moving vehicle" sign	57.7	37.2	18.4	10.6	30.6
Percent in good condition as assessed by site visitors	90.6	57.1	56.3	46.7	67.0
Miles driven per day as reported by primary operator					
Mean	5.2	5.4	3.8	3.3	4.8
Standard deviation	4.7	8.9	4.1	5.0	6.7

ROPS = rollover protective structure

not equipped with rollover protection. Our data also suggest that Kentucky has a lower overall prevalence of ROPS-equipped tractors than other states.^{4,13} This may be understandable given that other studies included farms with larger acreage as well as commercial farms; our data highlight the potentially greater hazards for family-operated farms in Kentucky and most likely in other states as well.

A primary objective of hazard surveillance is to identify populations at highest risk so that intervention efforts and resources can be appropriately focused. The data indicate that it is among the smaller farms, typically with fewer than 60 acres and only one or two tractors, that the risk associated with the operation of tractors without rollover protection is greatest. Approximately three-fourths of the one-tractor farms and 58.2% of the two-tractor farms in the state do not have ROPS-equipped tractors. Efforts to equip these farms with at least one ROPS tractor for the more hazardous farm tasks (mowing on slopes or operating the tractor with attached equipment such as rotary mowers ("bushhogs") should be encouraged. Additionally, farms in the eastern part of the state are least likely to have at least one ROPS-equipped tractor. Because of the hilly and uneven terrain in this part of the state, special intervention efforts related to tractor safety should be directed to this area.

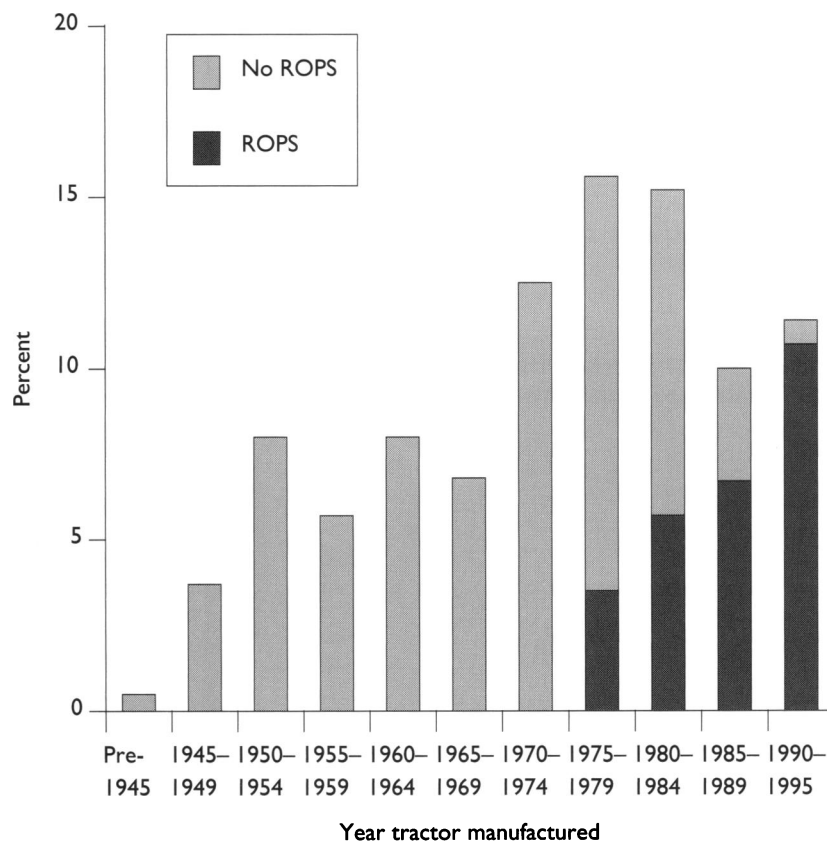
Results of the site visits indicate that farmers in Kentucky are not voluntarily retrofitting their older model tractors with rollover protection. Efforts to encourage the retirement of older, less safe tractors may be more successful than retrofitting programs. Given that the older model tractors are also not fitted with seat belts, PTO shields, and other safety devices, this approach would address other safety concerns as well.

If the distribution of tractor

age in the on-site survey is applicable to all tractors operating in the state, we estimate that 48% of tractors in the state were manufactured before 1975. Determination of ROPS availability for these older-model tractors and the trade-offs associated with retrofitting or replacing these tractors need to be considered in policy decisions regarding retrofitting, replacement, and tractor safety programs.

This population-based study is one of the few large survey initiatives to examine the prevalence of rollover protective structures on a representative sample of family-operated farms. Although the data collected during the on-site visits to 138 farms may not be generalizable to all family farms in the state, the percentage of ROPS-equipped tractors found in the on-site survey (27%) agreed closely with the percentage calculated from the FHADES data (29%), suggesting that the visit

Figure. ROPS status by age of tractor, 259 tractors inspected at 138 on-site farm visits



ROPS = rollover protective structure

data approximate the distribution of ROPS-equipped tractors in the state.

NIOSH has estimated that the current rate of rollover fatalities would be reduced 71% if all tractors were equipped with rollover protection.¹³ In Kentucky, this would mean retrofitting approximately 140, 123 tractors. Conservatively estimated, the cost of retrofitting existing tractors, excluding costs for administration of the program and enforcement, would be \$140 million. Projecting a 10-year time period for a program to retrofit existing tractors, a ROPS effectiveness of 71%, and an annual tractor-related fatality rate of 27 deaths per year, we estimated the cost per life saved to be \$731,000. This cost estimate is similar to figures generated by more refined cost-effectiveness analyses.^{4,24}

Given the current limited political support for farm safety regulatory programs, national legislation mandat-

ing ROPS-equipped tractors is unlikely. Reducing tractor-associated fatalities and injuries will require statewide and community intervention programs that encourage the voluntary retrofitting of tractors that can accommodate ROPS, retirement of older model tractors, and education regarding safe tractor operation and the importance of farm tractor safety equipment including seat belts, power take-off shields, and "slow moving vehicle" signs.

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