Adoption of Rollover Protective Structures (ROPS) on U.S. Farm Tractors by State: 1993-1995, 2001, and 2004

D. L. Hard, J. R. Myers

ABSTRACT. *This research compares state-level rollover protective structure (ROPS) prevalence rates from the early and mid-1990s to those observed in the years 2001 and 2004. In addition, state-level ROPS prevalence rates are compared to state-level tractor overturn fatality rates. Tractor data for 1993-1995 and for 2001 and 2004 for all tractors and ROPS-equipped tractors in use on U.S. farms were derived from surveys conducted for NIOSH by the USDA-NASS. Changes in ROPS prevalence rates at the state level between the two time periods were assessed using a two-sample paired t-test with unequal sample sizes. Poisson regression was used to assess the association between ROPS prevalence rates and tractor overturn fatality rates at the state level. Overall, 49 of the 50 states had an observed increase in the percentage of farm tractors equipped with ROPS from 1993-1995 to 2001 and 2004. This increase was statistically significant for 34 states. Large shifts in ROPS prevalence were found within individual states and in clusters of states. These include a major increase in the southeastern U.S. and some western states. However, a core of states in the northeast (many of them in or near the Appalachian Mountains) through the upper midwest remain in the bottom quartile for ROPS prevalence. For the years 1992 through 2004, the highest fatality rates were observed in many of the same states that were identified previously as having persistently low ROPS prevalence rates. There is a clear relationship between low state-level ROPS prevalence rates and high state-specific tractor overturn fatality rates. While progress has been made in increasing the percentage of ROPS-equipped farm tractors, it is projected that ROPS prevalence rates will not reach a protective level nationally until after 2015. Regionally, the northeast and midwest will not reach protective levels of ROPS-equipped tractors until after 2020. Based on the adoption rates observed, tractor overturn rates will likely continue to be a more localized, but significant, public health issue for several states beyond the year 2020. The results of this study show the geographic areas of the U.S. where the greatest need exists, and where a greater emphasis should be placed on ROPS promotion activities. However, addressing this public health issue on a large scale will require resources and an organized commitment, which have historically been lacking.*

Keywords. *Risk, Rollover protective structure, Safety, Tractor.*

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The authors are **David L. Hard, ASABE Member,** PhD, Agricultural Safety and Health Scientist, and **John R. Myers,** MSF, Mathematical Statistician, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, West Virginia. **Corresponding author:** David L. Hard, National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, West Virginia; phone: 304-285-6068; e-mail: dlh6@cdc.gov.

It has long been recognized that tractor fatalities are the leading cause of death for agricultural production workers in the U.S. (Bobick and Jenkins, 1992; Fiedler et al., 1998; Purschwitz and Field, 1990; Hard et al., 1999; Hard et al., 2002; Hayden et al., 1995; Karlson and Noren, 1979; Murphy, 1985, 1990; Murphy and Ambe, 1996; Murphy and Kassab, 2001; Meyer, 2005; Myers, 1989, 1990; Myers et al., 1998; Purschwitz and Field, 1986). There was an average of about 200 tractor-related fatalities annually between 1992 and 2005 in the U.S. Tractor overturns accounted for 1,412 of these deaths (NIOSH, 2006), representing half of all tractor-related deaths and about 1/3 of all deaths in the agricultural production industry during that 14-year time period.

Agricultural tractor overturn deaths have been an identified problem since the advent of the internal combustion engine tractor (Arndt, 1971; MacCollum, 1984). The rollover protective structure (ROPS) was developed to protect tractor operators from death and disability due to tractor overturns by providing a protective zone for the tractor operator in the event of a tractor overturn. The effectiveness of ROPS has been well documented (Lehtola et al., 1994; Springfeldt et al., 1998; Thelin, 1998; Reynolds and Groves, 2000; Myers et al., 2008). Estimates of the effectiveness of ROPS in preventing deaths have ranged from 71% to 99% depending on whether operators wear seatbelts on ROPS-equipped tractors (NIOSH, 1993; Pana-Cryan and Myers, 2002; Hallman, 2005; Cole et al., 2006).

Increasing the use of ROPS on tractors has long been a recognized public health need (NCASH, 1989; NIOSH, 1992) and has been shown to be a cost-effective means of reducing fatalities from tractor overturns (Kelsey and Jenkins, 1991; Myers and Snyder, 1995; Pana-Cryan and Myers, 2000; Owusu-Edusei, 2008). In 1985, the American Society of Agricultural Engineers (ASAE; now the American Society of Agricultural and Biological Engineers, ASABE) adopted a voluntary standard (S318) that encouraged tractor manufacturers to install ROPS and seatbelts on all new tractors for sale in the U.S. market as standard equipment (*ASAE Standards*, 1985), which would be calculated into the base price of the tractor. This removed the necessity of having farmers order the ROPS as an option or accessory. All major tractor manufacturers agreed to adopt this standard, and since 1986, nearly all new agricultural tractors sold in the U.S. have been equipped with ROPS and seatbelts as standard equipment. Analysis of tractors by age and ROPS usage in the U.S. indicates that most of the increase in ROPS-equipped tractors in the U.S. is due to the sale of new tractors equipped with ROPS since 1985, not ROPS retrofit efforts for older tractors (Loringer and Myers, 2008; Myers, 2003).

Recent research has documented the increase in the prevalence of ROPS on farms at the national and regional level (Loringer and Myers, 2008); however, that research did not look at the changes in ROPS prevalence at the state level. The purpose of this research was to compare state-level ROPS prevalence rates from the early and mid-1990s to the rates observed in the years 2001 and 2004. In addition, state-level ROPS prevalence rates were compared to state-level tractor overturn fatality rates.

Methods

1993-1995 Tractor Data

Tractor data for calendar years 1993 through 1995 were obtained from the NIOSH Traumatic Injury Surveillance of Farmers (TISF). The TISF was an occupational injury mail survey conducted for NIOSH by the USDA National Agricultural Statistics Service (NASS) between 1994 and 1996. The TISF used a two-stage sampling design with 1,400 farm operators randomly sampled within a random sample of 16 to 18 states each year. States were stratified by region of the U.S. and were rotated to ensure that each state was sampled at least once during the three-year period (Myers, 1997, 1998, 2001). Nine states were included in the TISF twice between 1994 and 1996: California, Connecticut, Florida, Kansas, Massachusetts, Missouri, Pennsylvania, Rhode Island, and Virginia. For the TISF, a farm was defined as any operation with $1,000 or more of gross agricultural production within a calendar year. Participation in the TISF was voluntary. For the three TISF mail surveys conducted for the years 1993 through 1995, the overall response rates ranged from a low of 51.5% in 1993 to a high of 55.3% in 1994.

Data on farm tractors were collected as part of the TISF survey. The tractor section of the survey requested the farm operator to provide information on all farm tractors that met the following criteria: the tractor was rated at over 20 power-takeoff horsepower, and the tractor was used on the farm for farm work. The information requested included the make, model, model year, hours of use, and whether the tractor was equipped with a ROPS or a ROPS cab. For this study, all three years of TISF data were pooled to develop state ROPS prevalence estimates.

ROPS prevalence rates were derived by state as the simple proportion of all tractors reported by farm operators as having a ROPS. If the presence of a ROPS was unknown, it was assumed to not be equipped with a ROPS. Tractor data were pooled for those states with two years of data. Because data on farm tractors were clustered within farms, the number of farms responding to the TISF survey within each state was used as the sample size (n) for all statistical tests. For the nine states with two years of data, the sample size was set to the average number of responding farms within each state.

2001 and 2004 Tractor Data

Estimates of all tractors and ROPS-equipped tractors in use on U.S. farms for calendar years 2001 and 2004 were derived from the NIOSH Occupational Injury Surveillance of Production Agriculture (OISPA) surveys. The OISPA is a computer-assisted telephone interview (CATI) survey of farm operators conducted for NIOSH by USDA-NASS. The OISPA uses a stratified random sample of 25,000 farming operations across the U.S. Strata for the sample are the four geographical regions of the U.S. as defined by the U.S. Bureau of the Census (BOC, 1975). Samples are equally allocated within the four regions. As with the TISF, a farm was defined as any operation with $1,000 or more of gross agricultural production within a calendar year in the OISPA. The 2001 data were collected during February 2002 through April 2002; the 2004 data were collected between February 2005 and April 2005. Participation in OISPA surveys was voluntary. For the OISPA telephone surveys, the overall 2001 response rate was 61.0%; in 2004, the response rate increased slightly to 65.0%.

Data on farm tractors were collected in the OISPA through two questions: how many farm tractors are used on the operation for farm production purposes (excluding lawn tractors or collectibles) and, of these tractors, how many are equipped with ROPS. ROPS prevalence rates were derived for each state as the simple proportion of all tractors reported by the farm operators as having a ROPS. If tractors were reported on a farm but the number of tractors with ROPS was unknown, it was assumed that all tractors on that farm were not equipped with a ROPS. The 2001 and 2004 tractor data were pooled for all states. Because data on farm tractors were clustered within farms, the average number of farms responding to the OISPA survey within each state for the two survey years was used as the sample size (n) for all statistical tests.

Tractor Overturn Fatality Data

Data on tractor overturn fatalities were obtained from the Bureau of Labor Statistics (BLS) Census of Fatal Occupational Injuries (CFOI) for the years 1992 through 2004. The CFOI was developed by BLS for surveillance of work-related fatalities in the U.S. The fatality data cover all industries and occupations, and all ages. To be included in the database, cases must meet the following criteria: the decedent was (1) employed at the time of the event and (2) engaged in a legal work activity or present at the site of the incident as a requirement of his or her job (BLS, 2009a). CFOI data are compiled using a multi-source methodology, and generally cases are only included in the database if two sources indicate a work relationship. Source and event were coded using the Occupational Injury and Illness Classification System (OIICS) (BLS, 1992). BLS provides NIOSH with a detailed CFOI research file through a memorandum of understanding. The research file includes variables such as specific age and state of death; however, the file excludes data from New York City.

For this analysis, agricultural production sector fatalities (i.e., crop and livestock production) were selected using standard industry codes contained in the CFOI (OMB, 1987, 1997). Tractor overturn fatalities were selected based on both a primary source code for tractor (source = 8530) and an event code that indicated the fatality was the result of a highway or non-highway overturn (event = 4141 or 4233). Rates were calculated based on annual average agricultural production employment estimates for the years 1992 through 2004 derived from the BLS Current Population Survey (BLS, 2009b).

Statistical Analysis

Changes in ROPS prevalence rates at the state level between the two time periods were assessed using a two-sample paired t-test with unequal sample sizes. For the purposes of grouping states together into low to high ROPS prevalence rates, states were placed into four groups based on the quartiles for the ROPS prevalence rates. This was done separately for the two time periods. In addition, quartile estimates from the 2001 and 2004 time period were applied to state-specific ROPS prevalence rates from the 1993-1995 time period to provide a comparison of the relative change in ROPS prevalence rates among states.

To assess the association between ROPS prevalence rates and tractor overturn fatality rates at the state level, Poisson regression was used. The dependent variable for the model was the annual average tractor overturn fatality rate for each state during the 13-year period 1992-2004, with the independent variable being the observed pooled

ROPS prevalence rate within a state for the years 2001 and 2004. For the purposes of grouping states together into low to high overturn fatality rates, states were placed into four groups based on the quartiles of the observed 1992-2004 annual average state tractor overturn fatality rates.

Results

Changes in State ROPS Prevalence

For the time period 1993-1995, only five states had a ROPS prevalence rate over 50%: Arizona, Louisiana, Mississippi, Montana, and North Dakota (table 1). This increased to 22 states during the 2001, 2004 time period. The number of states reporting ROPS prevalence rates above 60% increased from one during the 1993-1995 time period (Arizona) to eight during 2001, 2004 (Alaska, Arizona, Arkansas, Delaware, Hawaii, Louisiana, Mississippi, and Nevada). Nevada was the only state with an observed prevalence rate above 70% during the 2001, 2004 time period.

Overall, 49 of the 50 states had an observed increase in the percentage of farm tractors equipped with ROPS from the 1993-1995 to the 2001, 2004 time periods (table 1). This increase was statistically significant for 34 states (Prb > t, $\alpha < 0.05$), with 21 showing an increase that was significant at an $\alpha < 0.0l$ level. Seven states had observed increases in ROPS prevalence rates of 20% or more (Alaska, 35.5%; Rhode Island, 27.2%; Delaware, 25.4%; Hawaii, 25.2%; Nevada, 24.3%; Washington, 20.2%; and Alabama, 20%), although the increases observed for Delaware and Hawaii were not statistically significant. An additional nine states had increases between 15% and 19.9%.

Ten states had a ROPS prevalence increase below 5% between the two time periods (Arizona, -1.6%; Colorado, 0.1%; Kansas, 0.7%; New Hampshire, 1.4%; North Dakota, 1.4%; Montana, 2%; Illinois, 4.5%; South Dakota, 4.6%; and Wisconsin, 4.7%). An additional 13 states had an observed increase of only 5% to 9.9% between the two time periods.

Figure 1 shows the percentage of farm tractors equipped with ROPS by state based on the quartiles of the 1993-1995 ROPS prevalence estimates. During this initial time period, the states with the highest percentage of ROPS were those that had prevalence rates >44.8% (fig. 1). States in the third and fourth quartile ranges (ROPS prevalence rates >37.7%) tended to be geographically clustered west of the Mississippi River and east of California, Oregon, and Washington (fig. 1). A second cluster of states in the upper two quartiles was also seen in the southern states of Mississippi, Alabama, and Georgia.

States in the first quartile range (ROPS prevalence rate <31.8%) were concentrated in a line starting in Connecticut, moving west through New York and Pennsylvania, then southwest through the states of Kentucky and Missouri (fig. 1), and in the Pacific Northwest (Alaska and Washington). States in the second quartile range were found to be clustered in the south Atlantic states (Maryland through South Carolina) and on the west coast (Oregon and California).

Figure 2 shows the percentage of farm tractors equipped with ROPS by state using the quartiles of the 2001, 2004 observed ROPS prevalence rates. The threshold for the fourth quartile range increased from 44.9% for the 1993-1995 period to 54.9%. The states in this highest group tended to be geographically concentrated in the south/

Table 1. Change in state ROPS prevalence rates on farm tractors: 1993-1995 vs. 2001, 2004.

State	1993-1995 ROPS		2001, 2004 ROPS			t	
	%	SE	%	SE	Diff.	Value	Prb > t[a]
Alabama	0.396	0.022	0.596	0.035	0.200	4.804	<0.0001*
Alaska	0.257	0.132	0.612	0.154	0.355	1.747	0.03811*
Arizona	0.649	0.027	0.633	0.060	-0.016	-0.238	0.2425
Arkansas	0.459	0.024	0.646	0.031	0.187	4.756	<0.0001*
California	0.357	0.025	0.549	0.017	0.192	6.339	<0.0001*
Colorado	0.468	0.022	0.469	0.025	0.001	0.019	0.4879
Connecticut	0.283	0.026	0.447	0.050	0.164	2.924	0.0065*
Delaware	0.439	0.088	0.693	0.197	0.254	1.177	0.1272
Florida	0.363	0.031	0.535	0.042	0.172	3.304	0.0005*
Georgia	0.415	0.025	0.561	0.038	0.146	3.222	0.0006*
Hawaii	0.399	0.035	0.651	0.054	0.252	3.928	0.0732
Idaho	0.425	0.022	0.548	0.028	0.123	3.413	0.0003*
Illinois	0.465	0.021	0.510	0.028	0.045	1.279	0.0986
Indiana	0.360	0.022	0.422	0.035	0.062	1.511	0.0637
Iowa	0.431	0.022	0.488	0.024	0.057	1.720	0.0416*
Kansas	0.478	0.023	0.485	0.029	0.007	0.178	0.425
Kentucky	0.272	0.021	0.426	0.026	0.154	4.622	<0.0001*
Louisiana	0.522	0.033	0.641	0.046	0.119	2.099	0.0192*
Maine	0.332	0.039	0.450	0.038	0.118	2.173	0.0158*
Maryland	0.352	0.029	0.411	0.070	0.059	0.778	0.2135
Massachusetts	0.353	0.037	0.453	0.041	0.100	1.809	0.0356*
Michigan	0.341	0.020	0.401	0.031	0.060	1.612	0.0525
Minnesota	0.402	0.024	0.439	0.025	0.037	1.058	0.144
Mississippi	0.531	0.030	0.608	0.039	0.077	1.551	0.0619
Missouri	0.317	0.021	0.444	0.022	0.127	4.155	<0.0001*
Montana	0.505	0.024	0.525	0.025	0.020	0.570	0.2822
Nebraska	0.436	0.029	0.523	0.031	0.087	2.065	0.0201*
Nevada	0.481	0.055	0.724	0.078	0.243	2.545	0.0084*
New Hampshire	0.435	0.053	0.449	0.050	0.014	0.188	0.4239
New Jersey	0.278	0.023	0.467	0.031	0.189	4.861	<0.0001*
New Mexico	0.380	0.029	0.471	0.037	0.091	1.929	0.0264*
New York	0.300	0.021	0.389	0.016	0.089	3.333	0.0005*
North Carolina	0.337	0.022	0.465	0.033	0.128	3.198	0.0005*
North Dakota	0.540	0.022	0.554	0.041	0.014	0.299	0.3821
Ohio	0.315	0.023	0.401	0.028	0.086	2.346	0.0089*
Oklahoma	0.448	0.026	0.519	0.026	0.071	1.922	0.0276*
Oregon	0.340	0.021	0.516	0.023	0.176	5.696	<0.0001*
Pennsylvania	0.248	0.019	0.385	0.013	0.137	5.974	<0.0001*
Rhode Island	0.167	0.081	0.439	0.099	0.272	2.125	0.0222*
South Carolina	0.343	0.024	0.495	0.047	0.152	2.895	0.0016*
South Dakota	0.452	0.023	0.498	0.040	0.046	0.999	0.1619
Tennessee	0.362	0.021	0.481	0.029	0.119	3.334	0.0004*
Texas	0.454	0.027	0.524	0.019	0.070	2.116	0.0174*
Utah	0.371	0.023	0.455	0.036	0.084	1.975	0.0221*
Vermont	0.398	0.034	0.479	0.035	0.081	1.664	0.049*
Virginia	0.376	0.021	0.525	0.037	0.149	3.526	0.0002*
Washington	0.285	0.021	0.487	0.025	0.202	6.193	<0.0001*
West Virginia	0.250	0.019	0.416	0.050	0.166	3.102	0.0004*
Wisconsin	0.269	0.019	0.316	0.025	0.047	1.498	0.064
Wyoming	0.424	0.043	0.536	0.041	0.112	1.893	0.0301*

[a] Asterisk (*) indicates statistical significance at the 0.05 level.

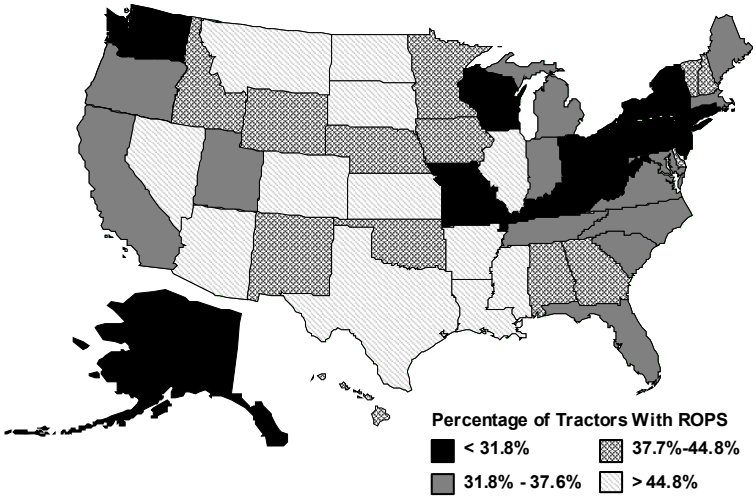

Figure 1. Percentage of farm tractors equipped with ROPS: 1993-1995 average. Quartiles are based on the 1993-1995 average state ROPS prevalence values.

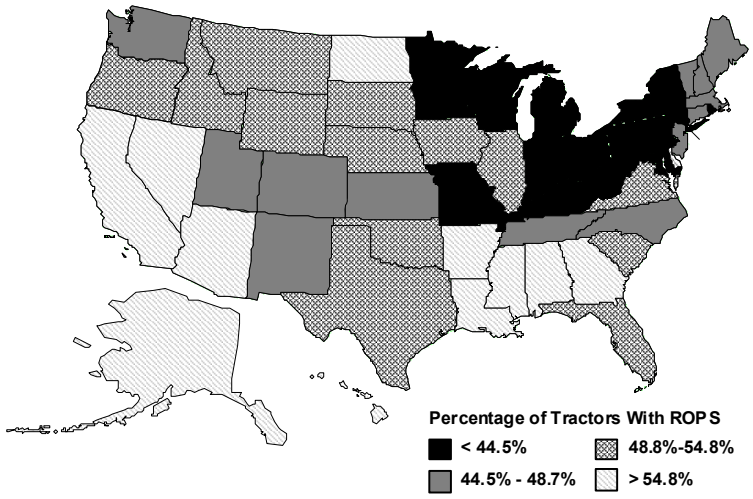

Figure 2. Percentage of farm tractors equipped with ROPS: 2001, 2004 average. Quartiles are based on the 2001, 2004 average state ROPS prevalence values.

southeast (Arkansas and Louisiana east to Georgia), southwest (Arizona, California, and Nevada), and far west (Alaska and Hawaii). This represents a geographic shift in the highest ROPS prevalence rates away from the central region of the U.S. seen in the 1993-1995 data (fig. 1).

States with ROPS prevalence rates in the third quartile range (48.8% to 54.8%) for the time period 2001, 2004 were found to be clustered along a line of states starting in Oregon, moving east to South Dakota, and then due south to Texas. States in the first

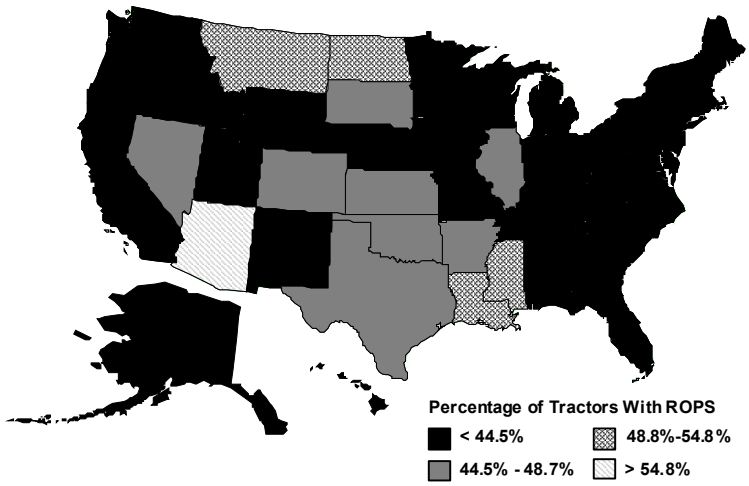

Figure 3. Percentage of farm tractors equipped with ROPS: 1993-1995 average. Quartiles are based on the 2001, 2004 average state ROPS prevalence values.

quartile range (ROPS prevalence rate <44.5%) were still concentrated in the northeast corridor, following the Appalachian Mountains from New York, Pennsylvania, and West Virginia through Ohio, Kentucky, and Missouri (which contains the Ozark Mountains); however, the western part of this cluster had moved north to include Michigan and Minnesota (fig. 2) compared to the 1993-1995 time period. States in the second quartile range for this later time period were clustered in the northern New England states (Connecticut up through Maine) and in the mountain states of Colorado, New Mexico, and Utah.

The changes seen between figures 1 and 2 represent shifts in each state's rankings over time due to the overall increased prevalence of ROPS-equipped tractors in the U.S. that occurred between the two time periods. Because the quartile ranges changed dramatically between the 1993-1995 and 2001, 2004 time periods, i.e., the highest quartile of 1993-1995 (>44.8%) was now almost the lowest quartile of 2001 and 2004 (<44.5%), it was difficult to visualize the magnitude of change that occurred between the two time periods for each state. In order to place the two time periods on an equal scale, the 1993-1995 state ROPS prevalence rates were grouped using the quartile ranges derived for the 2001, 2004 ROPS prevalence estimates (fig. 1).

In figure 3, all states originally classified in the 1993-1995 second and third quartile ranges have been re-classified into the 2001, 2004 first quartile range, with the exception of Oklahoma, which was reclassified into the second quartile range. In addition, all but one state (Arizona) ranked in the fourth quartile range were reclassified into the second (seven states) or third quartile range (four states). Because of these changes, states in New England and the southeast were reclassified into the lowest quartile range, moving the entire eastern U.S. into this category. In addition, much of the midwest and mountain states were moved into the lower two quartiles when viewed using the 2001, 2004 quartiles.

In comparing figure 3 to figure 2, large shifts in the prevalence of ROPS within individual states and clusters of states are more evident. These include the major in-

crease in the prevalence of ROPS in the southeastern region of the U.S.; the major increase in ROPS prevalence in the western states of Alaska, California, Hawaii, and Nevada; the modest increase in ROPS prevalence in the remaining western and mountain states; the modest increase in ROPS in the west north central and west south central states (the Dakotas down through Texas); and the core of states in the northeast corridor (many of which have the Appalachian Mountains running through or bordering them) through the upper midwest, which remained in the bottom quartile for ROPS prevalence rates.

State Tractor Overturn Fatality Rates

Figure 4 shows the range of state average fatality rates for tractor overturn deaths in production agriculture for the years 1992 through 2004. The highest observed fatality rates over this time period occurred in many of the same states that were identified in figures 2 and 3 as having persistently low ROPS prevalence rates (New York, Pennsylvania, West Virginia, Ohio, Indiana, Kentucky, and Missouri). Other states in the upper quartile for fatality rates were Virginia, Tennessee, Illinois, and Iowa.

Some similarity can be seen between figures 4 and 2. The states that had the highest percentage of ROPS on tractors generally had lower fatality rates, whereas states with lower ROPS prevalence rates had higher tractor overturn fatality rates. The Poisson regression results for tractor overturn fatality rates regressed against state ROPS prevalence rates confirms this association (table 2). States in the lowest quartile range of the 2001, 2004 ROPS prevalence rates had a tractor overturn fatality rate-ratio of 5.34 compared to those states in the fourth quartile range, while states in the second quartile range had a rate-ratio of 3.22 when compared to those in the fourth quartile range. States in the third quartile range of the 2001, 2004 ROPS prevalence rates had a tractor overturn fatality rate-ratio of 2.32 compared to those states in the fourth quartile range, although the rate-ratio was not significant (table 2).

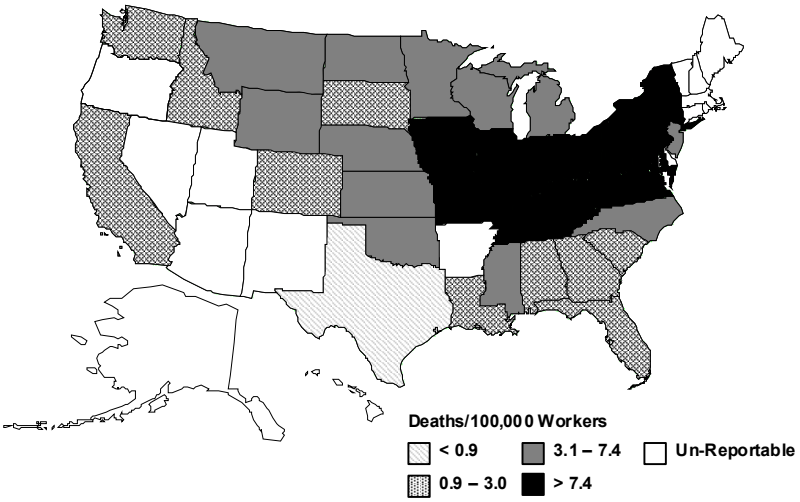

Figure 4. Tractor overturn fatality rates in production agriculture, 1992-2004, from the Census of Fatal Occupational Injuries (CFOI). Quartiles are based on the 1992-2004 average annual state fatality rates. Fatality rates were calculated by NIOSH; rates provided by BLS may differ.

Table 2. Poisson regression rate-ratios for state tractor overturn fatality rates by differing levels of ROPS prevalence rates within states.

State ROPS Prevalence Range (%)	Fatal Overturn Rate-Ratio (RR)	Lower 95% C.I. RR	Upper 95% C.I. RR
<44.5	5.34	2.18	13.10
44.5 to 48.7	3.22	1.16	8.99
48.8 to 54.8	2.32	0.90	6.02
>54.8	1.00	--	--

Discussion

Changes in State ROPS Prevalence Rates

Loringer and Myers (2008) reported that the overall prevalence of ROPS from 1993 to 2004 increased from 38% to 51% and concluded that this change was due primarily to the purchase of new tractors during that 12-year time period. This prevalence rate had increased to 59% by 2006 (NASS, 2008). The results of this current study found that, overall, ROPS prevalence rates increased in 49 of the 50 states over a similar period of time, with these increases being statistically significant in 34 of the states (table 1).

The largest change in ROPS prevalence rates were seen in the southeast region of the U.S., with the states of Alabama, Arkansas, Georgia, Louisiana, and Mississippi each moving into the highest ROPS prevalence quartile range (figs. 2 and 3). Florida, while not moving into the upper quartile range, did have a ROPS prevalence rate increase to above 50%, while South Carolina had a ROPS prevalence rate near 50% (table 1). Overall, the south region of the U.S. had the greatest increase in ROPS prevalence rates between 1993 and 2006, going from 38% to 65% during those 14 years (Myers, 2008; NASS, 2008). The second major area where increases in ROPS prevalence were seen was in the western states of Alaska, California, Hawaii, and Nevada. Two other states, Oregon and Idaho, each had ROPS prevalence rates above 50%.

As shown in figures 2 and 3, the New England states and New Jersey all moved from the lowest quartile range to the second quartile range between the 1993-1995 and 2001, 2004 time periods. In addition, while Pennsylvania remained in the lowest quartile range, it exhibited a 13.7% increase in its estimated ROPS prevalence rates between the two time periods. Overall, the northeast region of the U.S. had the second highest increase in ROPS prevalence rates between 1993 and 2006, going from 29% to 51% (Myers, 2008; NASS, 2008). States in the midwest part of the U.S. all had ROPS prevalence rate changes below 10% between the two time periods, with the exception of Missouri (12.7%; table 1). The midwest states as a group had the lowest increase in ROPS prevalence rates between 1993 and 2006, moving from 40% to 56% (Myers, 2008; NASS, 2008).

State ROPS Prevalence Rates and Tractor Overturn Fatality Rates

The results presented here support the importance of ROPS as a means of reducing tractor overturn fatality rates. Myers and Hendricks (2010) found a statistically significant decrease in tractor overturn fatality rates in the U.S. agricultural production industry between 1992 and 2007. They found that this decrease coincided with an increase in the ROPS prevalence rate on U.S. farm tractors from 38% in 1993 to 59% in 2006. The five-fold increased risk for tractor overturn deaths in states that had ROPS

prevalence rates below 44.5% during the 2001, 2004 time period and the three-fold increased risk in states with ROPS prevalence rates between 44.5% and 48.7% during the same time period demonstrate the influence that ROPS can have on reducing overturn deaths on farms in the U.S. (table 2).

Historical data from Sweden has shown a clear association between the prevalence of ROPS-equipped tractors and tractor overturn fatality rates (Springfeldt et al., 1998; Thelin, 1998), with other European countries having a similar experience (Springfeldt 1996). The effectiveness of ROPS has also been reported by others (Lehtola et al., 1994; Myers et al., 2008; Reynolds and Groves, 2000). The Swedish experience indicated that as ROPS prevalence rates increased, overturn fatality rates initially declined and then stabilized for ROPS prevalence rates between 40% and 75%. Only when ROPS prevalence rates reached between 75% and 80% did tractor overturn fatality rates begin to fall near zero (Springfeldt et al., 1998; Thelin, 1998). As shown in table 1, the highest ROPS prevalence rate found in this study for the 2001, 2004 time period was 72.4% in Nevada, with six other states having rates above 60% (Alaska, Arizona, Arkansas, Hawaii, Louisiana, and Mississippi). While no state had a ROPS prevalence rate at the 75% threshold suggested by the Swedish data, the upper 95% confidence limits for Alaska, Arizona, Hawaii, and Nevada were above 75%. However, national agricultural production tractor overturn fatality rates appear not to have been impacted during the 1992 to 2004 time period (fig. 5).

In an analysis of tractor overturn fatality rates between 1992 and 2007, Myers and Hendricks (2010) found that fatality rates were greater with increasing age, for farm family members, for crop operations, and for farming operations in the northeast and midwest regions of the U.S. They also reported a statistically significant decrease in tractor overturn fatality rates in the south region of the U.S., a finding likely influenced by the large increases in ROPS prevalence rates identified earlier in the states of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, and Florida. Myers and Hendricks (2010) also found that tractor overturn fatality rates for this 16-year time period decreased significantly in the northeast region of the U.S. (i.e., the New England states, New York, Pennsylvania, and New Jersey), which were the group of states that had the second highest increase in overall ROPS prevalence rates between 1993 and 2006 (Myers, 2008; NASS, 2008).

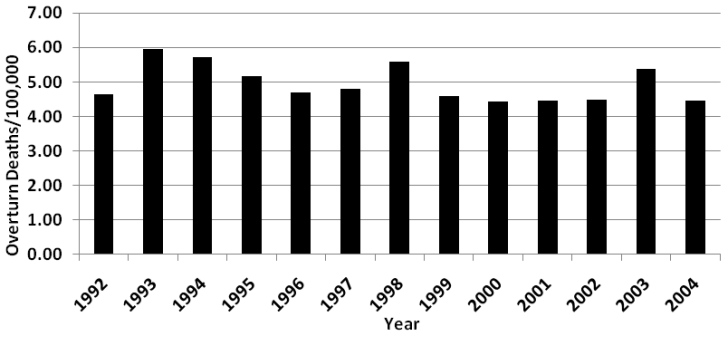

Figure 5. Crude tractor overturn fatality rates per 100,000 agricultural production workers by year, 1992 to 2004. This research was conducted with restricted access to BLS CFOI data (data exclude New York City). Rates were calculated by NIOSH and may differ from those published by BLS.

For the western U.S., Myers and Hendricks (2010) identified a decreasing fatality rate, but this decrease was not statistically significant. The states in the western region of the U.S. had the third highest ROPS prevalence rate increase between 1993 and 2006 at 19% (Myers, 2008; NASS, 2008). One problem reported by Myers and Hendricks (2010) in finding a statistically significant decrease in tractor overturn fatality rates in the west was the historically low number of tractor overturns seen in this region of the country (Myers et al., 1998). The midwest was the region of the U.S. found by Myers and Hendricks (2010) to have an increasing tractor fatality rate between 1992 and 2007, although this trend was not statistically significant. Interestingly, the midwest region also had the lowest increase in ROPS prevalence rates between 1993 and 2006 (Myers, 2008; NASS, 2008).

Factors Influencing State ROPS Prevalence Rates

Loringer and Myers (2008) identified several factors that were associated with lower ROPS prevalence rates on farms: farm operators over the age of 64 years, gross farm sales below $10,000, farming part-time, farming in the northeast and midwest regions of the U.S., farming small acreages, and being a livestock operation. Myers (2009a) identified many of these same factors as indicators of low ROPS prevalence rates on farms operated by racial minorities. Myers (2009b), using a multivariate logistic regression of state-level farming statistics from the 2002 Census of Agriculture, found that low farm income levels, small farm acreages, low numbers of hired farm workers, and high numbers of older, low-horsepower tractors were all associated with states with low ROPS prevalence rates during the 2001, 2004 time period.

Factors such as low value of sales, small farm acreages, part-time farming, low use of hired farm workers, and continued use of older farm tractors can all be viewed as differing measures of the economic status of the farming operation and, as such, are indicators of a farm operator with limited resources. These limited-resource farmers find it too costly to purchase new ROPS-equipped tractors or retrofit ROPS on older tractors, even if the tractors continue to be used for decades (Struttmann et al., 2001; Hallman, 2005). For these operators, money spent on ROPS would no longer be available for production-oriented expenses needed for the farm enterprise, a business decision for which they perceive few benefits (Sorensen et al., 2008). Sanderson et al. (2006) drew this same conclusion, suggesting that the reason farmers do not use ROPS may have more to do with economics and the size of the farming operation than with safety and health information encouraging them to use ROPS.

Other reasons farm operators have given for not using ROPS include: the issue of ROPS interfering with farm operations where low clearances are an issue (e.g., tractors used in orchards, getting tractors into farm buildings); the belief, particularly among older farmers, that they know how to control a tractor, making ROPS unnecessary (Whitman and Field, 1995; Arcury, 1997; Fiedler et al., 1998); and the difficulty involved in installing a ROPS on an existing tractor (Hallman, 2005).

Conclusion

There is a clear relationship between states that have low ROPS prevalence rates and high state-specific tractor overturn fatality rates. While progress has been made in increasing the percentage of ROPS-equipped farm tractors, it is occurring at a slow

rate. Based on ROPS prevalence rates in 1993, Myers and Snyder (1995) estimated it "will require more than two decades to obtain a high level of ROPS use (e.g., over 70% of exposure) at the present rate of influx of ROPS on U.S. farms." Their projected ROPS prevalence rate for 2003 was similar to that reported by Loringer and Myers (2008) for 2004 (49% and 51%, respectively). By 2006, the national ROPS prevalence rate had increased to 59% nationally (NASS, 2008). Based on these ROPS adoption rates, ROPS prevalence rates will not reach a protective level nationally until after 2015. Currently, the northeast and midwest regions of the U.S. will not reach protective levels of ROPS-equipped tractors until after 2020. Finally, based on the adoption rates observed, tractor overturn rates will likely continue to be a more localized, but significant, public health issue for several states beyond the year 2020.

Numerous studies have indicated the number of lives that would be saved if ROPS were installed on all farm tractors in the U.S. and the cost-benefit that ROPS bring to society (Myers and Snyder, 1995; Pana-Cryan and Myers, 2000; Owusu-Edusei, 2008). However, there has been little societal pressure inside or outside of the farming community to place ROPS on farm tractors. While it is clear that economics are an issue, the belief within the farming community that ROPS are not a necessity remains an important barrier (Sorensen et al., 2008).

Various suggestions have been made on how to achieve increased ROPS usage on farm tractors in the U.S., but they all have their limitations (Karlson and Noren, 1979; NCASH, 1989; Kelsey and Jenkins, 1991; Myers and Snyder, 1995; Donham et al., 1998; Freeman, 1999; Reynolds and Groves, 2000; Harris et al., 2002; Swenson, 2004; Hallman, 2005; Harris et al., 2005; Sorensen, 2006; Owusu-Edusei and Biddle, 2007; VFB, 2008). The results presented here show the geographic areas of the U.S. where the greatest need exists and where a greater emphasis should be placed on ROPS promotion activities. However, addressing this public health issue on a large scale will require funding, manpower, and an organized commitment, all of which have historically been lacking.

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