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Effect of enhanced seat belt reminders on driver fatality risk

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ABSTRACT

Objective: Enhanced seat belt reminders in automobiles have been shown to increase belt use rates by approximately 3 percentage points. The objective of this study was to estimate the effect of enhanced seat belt reminders on driver fatality risk. *Method:* Data included all passenger vehicle driver deaths and vehicle registration counts in the United States for calendar years 2000-2007. Driver fatality rates per vehicle registration per year were compared for otherwise identical vehicle models with and without enhanced seat belt reminders. *Results:* Driver fatality rates were 6% lower for vehicles with enhanced seat belt reminders compared with vehicles without enhanced belt reminders. After adjusting for vehicle age differences, the estimated effect of enhanced belt reminders on driver fatality risk ranged from a 9% reduction for General Motors vehicles to a 2% increase for Honda vehicles. Combining all manufacturers, enhanced belt reminders reduced fatality risk by approximately 2%. Although not statistically significant, the 2% reduction in fatality risk agrees with what should be expected from a 3 percentage point increase in seat belt use rates. *Conclusions:* Enhanced seat belt reminders have raised driver belt use rates and reduced fatality rates, but more aggressive systems may be needed for some drivers. It can be inferred that nonfatal injury rates also have been reduced. *Impact on Industry:* Manufacturers should be encouraged to put enhanced seat belt reminders on all vehicles as soon as possible.

1. Introduction

Seat belts have been available in automobiles since the 1950s, but it has been difficult to convince drivers and their passengers to use them (Kahane, 2004). Government agencies and highway safety advocates around the world have attempted to increase belt use rates through public education campaigns, legislation, and special enforcement programs. Progress has been slow, and there continues to be a hardcore group of drivers who resist using seat belts. In the United States in 1994, only 58% of front-seat occupants were using seat belts, even though it was required by law in 47 of the 50 states. By 2008 the national use rate had risen to 83% (Pickrell & Ye, 2008).

Evans (1991) derived a formula for the proportion of deaths (or injuries) that could be prevented in a given year if belt use rates were higher. The formula is $e\,(u_2 - u_1) / (1 - e\,u_1)$, where e represents the proportional reduction in fatality (or injury) risk due to belt use and u_1 and u_2 represent the actual and hypothetical belt use rates, respectively. It is estimated that three-point seat belts reduce the likelihood of driver fatality in a crash by 45% and reduce the likelihood of moderate to serious injury by 60% (National Highway Traffic Safety Administration [NHTSA], 2001). Then, for example, an increase in the belt use rate from 83% to 90% could reduce the number of driver deaths by approximately 5% and the number of moderate-to-seriously injured drivers by approximately 8%. An increase to 100% belt use could reduce the number of driver deaths by approximately 12% and the number of moderate-to-seriously injured drivers by approximately 20%.

Evans (1991) presented a more complicated version of his formula taking into account the expectation that drivers who do not use seat belts are more likely to crash than drivers who use seat belts. This adjustment requires an estimate of the relative crash risk for nonusers and users. No precise estimate of the relative crash risk is available, but it can be shown that the adjustment would produce slightly higher values for the effects of increased seat belt use (i.e., the additional drivers being protected are those at high risk).

Since 1975, Federal Motor Vehicle Safety Standard (FMVSS) 208 has required that all new passenger vehicles sold in the United States display a warning light and sound an audible signal for 4-8 seconds after ignition if the driver seat belt is not fastened (39 FR 42692). The standard, however, does not prohibit signals that last more than 8 seconds. In an effort to boost seat belt use, many automakers have increased the duration of these belt reminders.

An enhanced seat belt reminder system was introduced by Ford in some of its cars and SUVs in model year 2000. It has been standard equipment on all Ford models since 2002. If the driver seat belt is unfastened the system chimes for 6 seconds, pauses for 30 seconds, then chimes again for 6 seconds. This sequence continues for up to 5 minutes if the seat belt remains unfastened. Williams, Wells, and Farmer (2002) evaluated the effects of the Ford system on driver seat belt use. Based on observations of approximately 2,300 drivers arriving

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for service at Ford dealerships in Oklahoma, the authors reported a belt use rate of 76% for drivers with enhanced belt reminders compared with 71% for those without enhanced belt reminders.

Honda began phasing in an enhanced seat belt reminder system in model year 2004, and it has been standard equipment on all models since 2006. For most current Honda models the intermittent sequence of chimes continues indefinitely if the driver seat belt remains unfastened. Based on observations of more than 1,600 drivers arriving for service at Honda dealerships in Pennsylvania, Ferguson, Wells, and Kirley (2007) reported a belt use rate of 90% for drivers with enhanced belt reminders compared with 84% for those without enhanced belt reminders.

Freedman, Lerner, Zador, Singer, and Levi (2009) compared seat belt use among front-seat occupants with and without enhanced belt reminders based on a national sample of more than 39,000 vehicles. Observations were collected around shopping malls, office parks, and similar business centers with high traffic volume. After adjusting for potentially confounding effects of location, vehicle age, and occupant age and gender, the authors estimated that enhanced belt reminders increased both driver and passenger seat belt use by approximately 3 percentage points.

Enhanced seat belt reminders also have been effective at raising belt use rates in Europe. Based on observations of more than 11,000 drivers in seven countries, Lie, Krafft, Kullgren, and Tingvall (2008) reported a belt use rate of 98% for drivers with enhanced belt reminders compared with 86% for those without enhanced belt reminders.

Most automakers now include enhanced seat belt reminders in at least some of their vehicles. If, as the research seems to show, enhanced belt reminders cause more drivers to use belts, then these drivers should be better protected in a crash. This should be reflected in a decline in deaths and serious injuries. Applying the formula of Evans (1991), a 3 percentage point increase in the seat belt use rate should reduce the number of driver deaths by approximately 2%. The objective of the present study was to directly estimate the effect of enhanced seat belt reminders on driver fatality risk in the United States.

2. Method

Vehicle models included in the study were those that changed from no enhanced seat belt reminders available in one model year to enhanced belt reminders as standard equipment in a later model year without any other significant design changes. Enhanced belt reminders were defined as any belt reminders with both a visual and audio component lasting longer than the 4-8 second requirement of FMVSS 208. Other significant design changes included changes in vehicle size, availability of driver airbags, and availability of electronic stability control, all of which have been shown to affect driver fatality risk. Model years were restricted to at most the last 2 years without enhanced belt reminders and the first 2 years with enhanced belt reminders.

Records of driver deaths in relevant vehicles were extracted from the 2000–2007 files of the Fatality Analysis Reporting System, a federal database of fatal crashes occurring in all 50 states. Vehicle registration counts by vehicle model, model year, and calendar year were obtained from the National Vehicle Population Profile of R.L. Polk and Company. For each vehicle model, data were restricted to calendar years with exposure for both pre-belt reminder and belt reminder vehicles. In other words, if enhanced belt reminders first appeared in model year 2005, then the death and registration data for that model were restricted to calendar years 2005-2007.

If enhanced belt reminders have no effect on driver fatality risk, then fatality rates per registration should be approximately the same for the pre-belt reminder and belt reminder versions of each model. Thus the expected fatality count for the enhanced belt reminder version should be the product of the fatality rate for the pre-belt reminder version and the registration count for the belt reminder version. In this way expected fatality counts were computed for enhanced belt reminder versions of each of the relevant vehicle models. The risk ratio was defined as the sum of the observed fatality counts for enhanced belt reminder vehicles divided by the sum of the expected counts. A risk ratio significantly less than one could be taken as evidence that enhanced belt reminders reduce fatality risk (i.e., fewer fatalities than otherwise expected). Ninety-five percent confidence limits on the risk ratio were computed as follows (Silcocks, 1994):

$$\text{lower limit} = \beta_{0.025}(O, E + 1) / [1 - \beta_{0.025}(O, E + 1)] \text{ and}$$

$$\text{upper limit} = \beta_{0.975}(O + 1, E) / [1 - \beta_{0.975}(O + 1, E)],$$

where O is the sum of observed fatalities, E is the sum of expected fatalities, and $\beta_p(x, y)$ is the p^{th} percentile from the beta distribution with parameters x and y.

The comparisons were across model years but within the same calendar years, so vehicles without enhanced belt reminders were consistently older than vehicles with enhanced belt reminders. Farmer and Lund (2006) presented evidence that even minor differences in vehicle age could affect fatality rates. To account for these age effects, expected fatality counts were divided by various adjustment factors depending on the average ages of vehicles with and without enhanced belt reminders. For example, the risk of driver death for a 2-year-old model is approximately 2% higher than that for a 1-year-old model. Thus, for any vehicle model for which the pre-belt reminder versions averaged 2 years old and the belt reminder versions averaged 1 year old the expected fatality count was divided by 1.02.

3. Results

Driver fatality rates were compared between model years with and without enhanced seat belt reminders only if there were no other significant safety-related changes. So, for example, the 2004 model Honda Accord with enhanced belt reminders was compared with the 2003 Accord without enhanced belt reminders. However, the 2005 Honda Accord was excluded from the comparison because side airbags became standard equipment in that year. All years of the Honda CR-V were excluded from the analysis because both enhanced belt reminders and side airbags first became standard equipment in 2005. The Honda and Acura models and model years included in the analysis are listed in Table 1.

The two-door Honda Accord without enhanced belt reminders (model year 2003) had 20 driver deaths and 292,589 vehicle-years of exposure during calendar years 2004-2007, so the driver fatality rate was 68.4 deaths per million vehicle-years. If that rate was approximately the same as that for the two-door Accord with enhanced belt reminders (model year 2004), then, based on 195,810 vehicle-years of exposure, one would expect about 13 deaths. There actually were 15 driver deaths in the two-door Accord with enhanced belt reminders, slightly more than expected. Of the 13 vehicle model/body styles in Table 1, five had more deaths than expected, six had fewer deaths, and two had the same number as expected. Overall the group of Honda/Acura vehicles with enhanced belt reminders had a fatality rate approximately 3% lower than that for similar models without enhanced belt reminders.

Similar calculations were conducted for relevant vehicles produced by other manufacturers. Table 2 summarizes the results. Individual results are presented for the five manufacturers with the greatest exposure: Ford, General Motors, Chrysler, Honda, and Toyota. The estimated effect of enhanced belt reminders on driver fatality risk ranged from a 13% reduction for General Motors vehicles to a 3% reduction for Ford and Honda vehicles. Combining all manufacturers, enhanced belt reminders reduced fatality risk by approximately 6%. This effect was statistically significant.

Table 1
Driver fatality rates for vehicles with and without enhanced seat belt reminders – Honda.

	Without enhanced belt reminders		With enhanced belt reminders				Confidence limits	
Vehicle model, style, and model years	Vehicle-years	Driver deaths	Vehicle-years	Driver deaths	Expected deaths	Rate Ratio	Lower	Upper
Honda Accord 2dr 03 vs. 04	292,589	20	195,810	15	13.38	1.12	0.50	2.54
Accord 4dr 03 vs. 04	1,372,055	51	1,247,525	56	46.37	1.21	0.80	1.82
Civic 2dr 02-03 vs. 04-05	755,174	75	541,713	54	53.80	1.00	0.68	1.49
Civic 3dr 02-03 vs. 04-05	72,241	17	33,659	1	7.92	0.13	0.00	0.94
Civic 4dr 02-03 vs. 04-05	1,461,426	114	1,151,377	86	89.81	0.96	0.70	1.30
Civic Hybrid 03 vs. 04-05	125,931	6	161,152	11	7.68	1.43	0.52	4.18
S2000 02-03 vs. 04-05	68,127	14	51,462	8	10.58	0.76	0.26	2.09
Insight 02-03 vs. 04-05	11,536	0	3,574	0	0.00	–	–	–
Pilot 4WD 03 vs. 04-05	435,066	12	833,036	19	22.98	0.83	0.43	1.59
Element 2WD 03-04 vs. 05-06	102,285	4	71,941	2	2.81	0.71	0.06	6.59
Element 4WD 03-04 vs. 05-06	245,747	9	130,167	6	4.77	1.26	0.32	5.37
Acura RSX 2dr 03-04 vs. 05-06	131,534	33	97,355	17	24.42	0.70	0.35	1.35
Acura TSX 4dr 04-05 vs. 06-07	160,049	3	91,254	3	1.71	1.75	0.19	26.79
	5,233,760	358	4,610,025	278	286.24	0.97	0.82	1.15

Table 2
Driver fatality rates for vehicles with and without enhanced seat belt reminders – All manufacturers.

	Without enhanced belt reminders		With enhanced belt reminders				Confidence limits	
Manufacturer	Vehicle-years	Driver deaths	Vehicle-years	Driver deaths	Expected deaths	Rate Ratio	Lower	Upper
Ford	33,163,621	3,634	27,106,466	2,775	2,864.22	0.97	0.92	1.02
General Motors	16,206,436	1,391	12,600,051	966	1,114.46	0.87	0.79	0.95
Chrysler	6,403,768	497	6,902,130	447	508.27	0.88	0.77	1.00
Honda	5,233,760	358	4,610,025	278	286.24	0.97	0.82	1.15
Toyota	4,997,105	281	4,020,709	209	233.82	0.89	0.74	1.08
Other*	6,429,914	430	4,549,489	270	268.70	1.00	0.85	1.19
	72,434,604	6,591	59,788,870	4,945	5,275.70	0.94	0.90	0.97

* Audi, BMW, Hyundai, Isuzu, Jaguar, Kia, Mazda, Mercedes, Mini, Mitsubishi, Porsche, Saab, Suzuki, Volkswagen.

Expected driver deaths for each vehicle model/body style were adjusted based on the age differences of vehicles being compared. For example, the average age of four-wheel-drive Honda Pilots without enhanced belt reminders (model year 2003) in the exposure data was 2 years. The average age of four-wheel-drive Honda Pilots with enhanced belt reminders (model years 2004-2005) in the exposure data was 1 year. Newer vehicles tended to have lower fatality rates than older vehicles (Farmer & Lund, 2006). Therefore the expected number of driver deaths was reduced to 22.98 / 1.02 = 22.53, still higher than the actual count of 19 deaths. After vehicle age-related reductions to the other expected counts in Table 1, the overall effect of enhanced belt reminders for Honda vehicles was an estimated 2% increase in the fatality rate (Table 3).

Table 4 summarizes results by manufacturer after adjusting for vehicle age. Vehicles with enhanced belt reminders were consistently newer than vehicles without enhanced belt reminders, so all rate ratios increased. The age-adjusted estimated effect of enhanced belt reminders on driver fatality risk ranged from a 9% reduction for General Motors vehicles to a 2% increase for Honda vehicles. Combining all manufacturers, enhanced belt reminders reduced fatality risk by approximately 2%, but the effect was not statistically significant.

Table 3
Driver fatality rates for vehicles with and without enhanced seat belt reminders, adjusted for vehicle age – Honda.

	Without enhanced belt reminders		With enhanced belt reminders				Confidence limits	
Vehicle model, style, and model years	Vehicle-years	Driver deaths	Vehicle-years	Driver deaths	Expected deaths	Rate Ratio	Lower	Upper
Honda Accord 2dr 03 vs. 04	292,589	20	195,810	15	13.38	1.12	0.50	2.54
Accord 4dr 03 vs. 04	1,372,055	51	1,247,525	56	46.37	1.21	0.80	1.82
Civic 2dr 02-03 vs. 04-05	755,174	75	541,713	54	50.28	1.07	0.72	1.61
Civic 3dr 02-03 vs. 04-05	72,241	17	33,659	1	7.40	0.14	0.00	1.03
Civic 4dr 02-03 vs. 04-05	1,461,426	114	1,151,377	86	83.94	1.02	0.75	1.40
Civic Hybrid 03 vs. 04-05	125,931	6	161,152	11	7.53	1.46	0.53	4.30
S2000 02-03 vs. 04-05	68,127	14	51,462	8	9.88	0.81	0.28	2.29
Insight 02-03 vs. 04-05	11,536	0	3,574	0	0.00	–	–	–
Pilot 4WD 03 vs. 04-05	435,066	12	833,036	19	22.53	0.84	0.43	1.63
Element 2WD 03-04 vs. 05-06	102,285	4	71,941	2	2.63	0.76	0.06	7.54
Element 4WD 03-04 vs. 05-06	245,747	9	130,167	6	4.46	1.35	0.33	6.01
Acura RSX 2dr 03-04 vs. 05-06	131,534	33	97,355	17	22.83	0.74	0.37	1.46
Acura TSX 4dr 04-05 vs. 06-07	160,049	3	91,254	3	1.68	1.79	0.19	28.26
	5,233,760	358	4,610,025	278	272.90	1.02	0.86	1.21

Table 4
Driver fatality rates for vehicles with and without enhanced seat belt reminders, adjusted for vehicle age – All manufacturers.

	Without enhanced belt reminders		With enhanced belt reminders				Confidence limits	
Manufacturer	Vehicle-years	Driver deaths	Vehicle-years	Driver deaths	Expected deaths	Rate Ratio	Lower	Upper
Ford	33,163,621	3,634	27,106,466	2,775	2,770.28	1.00	0.95	1.06
General Motors	16,206,436	1,391	12,600,051	966	1,061.07	0.91	0.83	0.99
Chrysler	6,403,768	497	6,902,130	447	477.95	0.94	0.82	1.07
Honda	5,233,760	358	4,610,025	278	272.90	1.02	0.86	1.21
Toyota	4,997,105	281	4,020,709	209	219.67	0.95	0.78	1.16
Other*	6,429,914	430	4,549,489	270	256.77	1.05	0.88	1.25
	72,434,604	6,591	59,788,870	4,945	5,058.65	0.98	0.94	1.02

* Audi, BMW, Hyundai, Isuzu, Jaguar, Kia, Mazda, Mercedes, Mini, Mitsubishi, Porsche, Saab, Suzuki, Volkswagen.

4. Discussion

Freedman et al. (2009) estimated that enhanced seat belt reminders increase driver belt use by 3 percentage points, which theoretically should reduce the number of driver deaths by approximately 2%. It was expected, then, that the effect of enhanced seat belt reminders on fatality risk would be very low. In fact, the age-adjusted effectiveness estimate based on direct analysis of fatality data was a 2% reduction in risk.

Other researchers have estimated higher effects on seat belt use for enhanced seat belt reminders of certain manufacturers. Williams et al. (2002) reported that enhanced belt reminders in Ford vehicles increased driver seat belt use by 5 percentage points. Ferguson et al. (2007) reported that enhanced belt reminders in Honda vehicles increased driver belt use by 6 percentage points. Theoretically a 5-6 percentage point increase in the belt use rate should reduce the number of driver deaths by approximately 4%. The Ford and Honda vehicles in the present study did not achieve 4% reductions, even before adjusting for vehicle age (Table 2). It may be that the estimates of Williams et al. (2002) and Ferguson et al. (2007) cannot be generalized to the entire driving population of the United States. Both studies were conducted at new car dealerships and were restricted to a single state.

There is some evidence that the effect of enhanced belt reminders on fatality risk differs by vehicle manufacturer (Table 4). However, Freedman et al. (2009) estimated only minor differences in the effects on driver seat belt use when comparing different enhanced belt reminder designs (increases ranged from 2.5 to 3.9 percentage points). Thus the variability in estimated effectiveness across manufacturers likely is due to differences in drivers rather than differences in design.

The 2% effectiveness estimate across all manufacturers is not statistically significant, but this may be due to the variability of results across vehicle models. Again, this probably stems from driver differences. Also, to reach statistical significance an estimate as low as 2% would require three times the vehicle exposure data available for this study. The lack of statistical significance is somewhat offset by the fact that the estimate agrees with the theory of Evans (1991) as applied to the results of Freedman et al. (2009).

When surveyed, approximately 98% of drivers claim to use seat belts at least some of the time (Boyle & Lampkin, 2008). The most common reasons given for sometimes not using belts are driving just a short distance (i.e., low perceived risk) and forgetting (Eby, Molnar, Kostyniuk, & Shope, 2005). Enhanced belt reminders should be effective for drivers who forget to fasten their seat belts. However, a reminder may be insufficient when a driver feels the seat belt is unnecessary. This could be especially problematic for young drivers, who have a tendency to underestimate risk. A more aggressive alarm may be required for such drivers. For example, a buzzer that sounds continuously when the driver seat belt is unfastened has been shown to dramatically increase use rates for teenagers (Farmer, Kirley, & McCartt, 2009). A continuous buzzer may not be acceptable to the general population of drivers. Freedman et al. (2009) suggested an alarm that begins as a simple reminder, then becomes more aggressive if the driver remains unbelted.

Consumer crash protection ratings in Europe include credits for enhanced seat belt reminders. Since 2002 Euro NCAP has added one point to the occupant protection score of any vehicle with an enhanced driver seat belt reminder. Additional points are gained if enhanced belt reminders extend to the front and rear-seat passengers. By 2005 more than half of the new car models sold in Europe had enhanced driver seat belt reminders (European Transport Safety Council, 2006). Japan has required enhanced driver seat belt reminders for all new cars sold there since 2005. Other countries such as the United States have strongly encouraged manufacturers to equip their vehicles with enhanced belt reminders.

There still are, however, a considerable number of new vehicles being sold without enhanced belt reminders. Approximately 10% of the new vehicle models for sale in the United States in 2008 did not have enhanced belt reminders for drivers. Availability of enhanced belt reminders for front and rear-seat passengers was even lower. There also are a great many older vehicles on the road without enhanced belt reminders. Seat belt use rates tend to be lower for rear-seat passengers and for occupants of older vehicles, so enhanced belt reminders potentially could be more effective for these groups (Boyle & Lampkin, 2008; Freedman et al., 2009).

Of the 21,647 driver deaths in the United States in 2007, only 3,442 were in vehicles that were known to have enhanced belt reminders. Based on a 2% effectiveness estimate, these enhanced reminders prevented approximately 70 deaths. So, although seat belt use rates in the United States continue to rise, there still is a great deal of potential benefit from enhanced belt reminders. NHTSA estimates that a seat belt use rate of 90% in all 50 states in 2007 would have prevented 1,652 deaths and 22,372 serious injuries (Starnes & Blincoe, 2009).

In summary, enhanced seat belt reminders have raised driver belt use rates and reduced fatality rates. Although not specifically examined here, it can be inferred that non-fatal injury rates also have been reduced. Manufacturers should be encouraged to put enhanced belt reminders on all vehicles as soon as possible and to extend these enhanced reminders to all seating positions. However, unless older vehicles are to be retrofit with enhanced belt reminders, other efforts to increase belt use will be even more important in the short term.

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