FIELD EFFECTIVENESS OF TWO RESTRAINT SYSTEMS: THE 3-POINT MANUAL BELT VERSUS THE 2-POINT-MOTORIZED-SHOULDER, MANUAL-LAP BELT

F.M. Streff
The University of Michigan
Transportation Research Institute
Ann Arbor, MI U.S.A.

ABSTRACT

The research question addressed in this paper is whether or not occupant death, injury, and ejection outcomes differ between vehicles equipped with 3-point manual belts versus 2-point-motorized-shoulder, manual lap (motorized/manual) belt systems. Census crash data sets for the states of Washington and Texas, and the Fatal Accident Reporting System (FARS) were subset to provide data on front-outboard occupants of Ford Escorts involved in crashes in calendar years 1981-1991. Logistic regression analyses showed that occupants of vehicles equipped with the motorized/manual system experienced 11.7% to 26.4% fewer K-A level injuries than occupants of vehicles equipped with the 3-point system. Similar analyses of FARS data showed lower ejection rates for occupants of vehicles with the motorized/manual system in both rollover and nonrollover crashes. The installation of the motorized/manual system provided a substantial safety benefit over the manual 3-point system in the time periods examined.

Automatic safety belt systems were designed in response to low manual belt use rates. When the (U.S.) Federal Motor Vehicle Safety Standard No. 208 was amended in 1984 to require a phase-in of automatic occupant protection systems beginning

with the 1987 model year, safety belt use in the U.S. was 14%. By 1990, the first calendar year in which all cars were required to be equipped with an approved form of automatic occupant protection, belt use had increased to only 49% (NHTSA, 1992).

Among the belt systems produced to improve the protection offered to persons unlikely or unwilling to "buckle up" themselves is a system incorporating; (a) a shoulder belt that moves around the occupant automatically when the vehicle door is closed and the ignition is engaged, (b) a lap belt that must be connected manually, (c) a knee bolster (hereafter this system will be referred to as the motorized/manual system). The purpose of this paper is to describe results of a study to determine if installation of the motorized/manual system provided a measurable safety benefit over manual 3-point belts.

Measures of the effectiveness of safety belts for preventing death and injury can be classified into two broad categories, potential and actual. Potential effectiveness (or "when used" effectiveness) refers to the ability of a given safety belt system to prevent death or injury when the system is **used properly**.

Nash (1989) estimated the potential effectiveness of the Toyota motorized/manual system for preventing deaths to be 40%. This effectiveness figure is based on a comparison of age-adjusted fatality rates (per car-year of exposure) for the Toyota Cressida (with motorized/manual system) and Nissan Maxima (with 3-point manual). However, Evans (1991) suggests that one should be cautious about interpreting this result because, "...comparing fatality rates for vehicles possibly purchased by different types of drivers for use in different driving environments may lead to incorrect inferences."

Evans (1991) examined the potential effectiveness of the shoulder belt component of the motorized/manual system for preventing deaths incorporating data from several sources and "a number of assumptions." He reports a shoulder belt only system is 29% effective in preventing death when used. While Evans does an adequate job in discussing the rationales behind his assumptions, it would appear that too much importance has been given to too few data to develop a definitive effectiveness measure.

Actual effectiveness (or "field" effectiveness) refers to the

ability of a given belt system to prevent death or injury considering the manner in which the belt system is actually used. Evans (1991) illustrates this point well by stating that based on his effectiveness estimates, a use rate of 86% for 3-point belts would be required to achieve the field effectiveness he estimated for the motorized/manual system (32%).

Reinfurt and Chi (1981) studied the field effectiveness of a similar system (detachable-automatic shoulder belt, knee bolster, no lap belt). This analysis found that crash-involved occupants in vehicles equipped with the automatic system experienced 20% to 30% fewer (K+A) injuries than those in the same vehicle type equipped with manual 3-point belts. The authors attribute all of the difference in field effectiveness to increased use of the shoulder belt.

NHTSA has also contributed to the discussion (1992, 1993). In 1992 and 1993, NHTSA released interim reports on the effectiveness of occupant protection systems. Although they used different data bases (i.e., FARS and NASS-CDS respectively), the overall conclusions were consistent. Namely, fatality risk is lower for cars with the motorized/manual system than the risk for manual 3-point belts at 1983 belt use rates, and cars equipped with the motorized/manual system have lower occupant ejection rates than cars with manual 3-point belts.

This paper expands upon earlier work examining the field effectiveness of the motorized/manual system. This study examines a single vehicle type, produced in large numbers, that changed over from manual to motorized/manual belt systems without substantial change to the vehicle platform (i.e., Ford Escort). Census crash data sets from two states (i.e., Washington and Texas), and FARS were used to enable an examination of the range of crash severities from property-damage-only to fatal.

METHODS

Census crash data sets for the states of Washington and Texas, and FARS were subset to provide all crash-involved front-outboard occupants in Ford Escorts for calendar years 1981-1991. Ford Escorts were selected because; (a) these

vehicles were equipped with 3-point manual belts until the manufacturer switched completely to the motorized/manual system in 1988 (b) Escorts underwent no substantial design change during the evaluation period other than the belt system change, and (c) a sufficient number of these vehicles are present in the vehicle population to conduct valid statistical comparisons.

Each occupant case in the subset included data on the year the crash occurred, the type of belt system installed in the vehicle (pre1987 model year=manual belt; model year 1988 and greater=motorized/manual system; model year 1987 was excluded because both systems were offered simultaneously), occupant age and police-reported injury severity, and vehicle damage severity. Case occupant injuries were dichotomized into cases in which occupants experienced fatal or serious (K or A-level) injuries and those who received lesser or no injury (B-level, C-level, and no injury). Cases subset from the FARS data sets also included whether or not the case vehicle overturned and the ejection status of each case occupant.

Several analyses were conducted for each data set. All analyses applied logistic regression to determine the extent to which injury outcome was related to the safety belt system available in the vehicle. The following logistic regression analyses were conducted for each data set:

- no covariates, calendar years 1981-1991,
- no covariates, calendar years 1988-1991,
- occupant age & vehicle damage severity as covariates, calendar years 1981-1991
- occupant age & vehicle damage severity as covariates, calendar years 1988-1991.

The analyses including data from 1981-1991 describe 11 years of crash experience, including the low belt use period of the early 1980's. Analyses of the time slice 1988-1991 describe differential effectiveness of the two systems as belt use became more prevalent with the advent of belt use laws in the U.S.

In addition, the FARS analyses included logistic regression analyses of the relationship between occupant ejections and restraint system type. These analyses were conducted for two crash subgroups, cases in which the vehicle overturned and cases where the case vehicle did not overturn.

RESULTS

The logistic regression analyses showed that occupants of vehicles equipped with the motorized/manual system experienced 11.7% to 26.4% fewer K-A level injuries than occupants of vehicles equipped with the 3-point system. Details from the analyses of the relationship between injury outcome and belt system are presented in Table 1.

The first column of Table 1 describes the calendar years of data included in the logistic regression analysis. The next two columns (headed by "Percent K-A Injuries") describe the proportion of crash-involved occupants that experienced K-A level injury. The "N=" refers to the total number of occupants from which the proportion was calculated. The "Covariates Used?" column describes whether or not the covariates (i.e., occupant age and vehicle damage severity) were included in the logistic regression model. The final column of the table describes the results of the logistic regression models, converting the logistic regression parameter estimate into an odds-ratio describing the proportion fewer K-A injuries experienced by occupants in vehicles equipped with the motorized/manual belt system and the estimates' associated p-values.

In addition to the analyses of the relationship between K-A injury and belt system, analyses were conducted to determine if there is a relationship between the likelihood of occupant ejection and the type of belt system installed in the vehicle. As shown in Table 2, occupants of vehicles equipped with the motorized/manual belt system experienced significantly lower ejection risk than those in vehicles equipped with the 3-point manual belt. This finding holds true for both vehicles that rolled over and those that did not.

Table 1
Results of K-A Injury Logistic Regressions

Calendar Years	Percent K-A Injuries		Covariates Used?	Percent Fewer K-A Injuries
	Manual belt	Motorized/ manual belt		
Washington				
1981-1991	3.25% N=18,820	2.57% N=3,698	No	21.4% (p=.03)
			Yes	21.9% (p=.04)
1988-1991	3.04% N=8,730	2.53% N=3,682	No	17.2% (p=.12)
			Yes	15.4% (p=.21)
Texas				
1981-1991	3.23% N=46,211	2.62% N=15,677	No	19.5% (p<.01)
			Yes	26.4% (p<.01)
1988-1991	2.96% N=18,099	2.62% N=15,609	No	11.7% (p=.06)
			Yes	15.1% (p=.02)
FARS				
1981-1991	72.2% N=5,838	68.3% N=1,238	No	17.2% (p<.01)
			Yes	19.4% (p<.01)
1988-1991	72.4% N=2,380	68.3% N=1,233	No	17.9% (p=.01)
			Yes	18.0% (p=.02)

Table 2 Results of Occupant Ejection Logistic Regressions (FARS)			
Calendar Years	Percent Rollover Crash Occupants Ejected		Percent Fewer Rollover Crash Occupants Ejected
	Manual belt	Motorized/ manual belt	
1981-1991	47.7% N=1,232	40.4% N=329	25.7% (p=.02)
1988-1991	46.4% N=490	40.2% N=328	22.3% (p=.08)
Calendar Years	Percent NonRollover Crash Occupants Ejected		Percent Fewer NonRollover Crash Occupants Ejected
	Manual belt	Motorized/ manual belt	
1981-1991	7.5% N=4,606	4.5% N=909	41.6% (p<.01)
1988-1991	8.3% N=1,890	4.5% N=905	47.2% (p<.01)

DISCUSSION

From the results of this study, one can conclude that the installation of the motorized/manual belt system provided a substantial safety benefit over the 3-point manual belt system. The motorized/manual system not only reduced the likelihood of death and serious injury relative to the 3-point system, but it also decreased the likelihood of ejection in both rollover and nonrollover collisions. The magnitude of the field effectiveness differences between the two systems was quite consistent across data sets and time periods, further supporting the benefit conclusion.

The focus of this study was the field or actual effectiveness of the belt systems for preventing death, serious injury, and ejection as the systems are actually used by crash-involved persons. While there is significant value in estimating the potential for systems to prevent injury when used properly, it

is essential that policy decisions be based on how these systems actually work in the field. We must be diligent in assessing how people react to and even disable otherwise effective systems.

Indeed, some concern has been expressed about the reduction of actual effectiveness of the motorized/manual system caused by persons destroying the shoulder belt component and/or persons failing to connect the lap belt component of the system (e.g., NHTSA 1992, 1993). Studies to date consistently report use of the motorized shoulder belt component of the system at or above 90%, however, lap belt use has been somewhat lower. Table 3 presents data on use of the lap belt in vehicles equipped with the motorized/manual system.

Table 3
Lap Belt Use in Vehicles Equipped with the Motorized/Manual System

Lap Belt Use	Method	Location	Author
29%	Roadside observation	North Carolina	Reinfurt et al., 1990
48%	Roadside observation	Wash., D.C. Chicago Los Angeles Philadelphia	Williams et al., 1989
66%	Crash investigation	Central Virginia	IIHS, 1992
70%	Roadside observation	Michigan	Streff et al., 1993

The data described in Table 3 provide valuable information on how effectiveness of the motorized/manual belt system may be impacted by individual behavior. That is, these belt systems may not be achieving their potential for injury prevention because of the number of persons failing to attach the lap belt component. On the other hand, even if the most

conservative belt use rates are true, the crash data show clearly that the motorized/manual belt system has provided significant safety benefits above those provided by manual 3-point belts alone.

It has been argued that the primary function of the lap belt component when used is ejection prevention while the primary function of the shoulder belt component when used is to prevent contacts within the vehicle interior (Evans, 1991). If this argument were true, and lap belt use was quite low, we could expect that there would be little to no difference in ejection rates between occupant of vehicles equipped with motorized/manual belt systems or manual 3-point belt systems as these systems are used by crash-involved occupants. This study found that occupants of vehicles equipped with the motorized manual belt system were less likely to be ejected from the vehicle in both rollover and nonrollover crashes when compared to occupants of vehicles with the manual 3-point belt. Whether this finding is due more to higher than estimated use of the lap belt component or greater efficacy of the shoulder belt is an empirical question.

An understanding of the potential for systems to achieve a given level of benefit is important so one can assess why the potential for the system is or is not reached and efforts can be implemented to remedy the systemic shortcomings. However, one cannot overlook the practical value of an understanding of how safety systems actually perform as they are used (and misused) by the consumer.

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