Overreporting and Measured Effectiveness of Seat Belts in Motor Vehicle Crashes in Utah

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Motor vehicle crashes are a leading cause of injury and mortality in the United States. The effectiveness of seat belt use has been difficult to study because of the unavailability of population-based crash data bases that include all noninjured occupants. The 1991 Utah Crash Outcome Data Evaluation System data base was developed to determine seat belt effectiveness. It includes occupants of all police-reported motor vehicle crashes. Seat belt effectiveness may be overestimated, however, because of self-reporting of seat belt use when crash occupants are questioned by police. The effect of misclassification of seat belt use on the calculated odds ratio associated with seat belt use was studied by using logistic regression models of four levels of injury. The odds ratio associated with seat belt use for any degree of injury was 0.448 [95 percent confidence interval (CI) 0.425 − 0.473]; the odds ratios associated with seat belt use for injuries requiring outpatient emergency care, hospitalization, or fatalities were 0.476 (95 percent CI 0.449 − 0.504), 0.203 (95 percent CI 0.170 − 0.241), and 0.148 (95 percent CI 0.097 − 0.226), respectively. Adjustment of the fraction of correct classification of seat belt use among reported belt users decreased the protective effect associated with seat belt use for all four levels of injury. This is consistent with overestimation of seat belt effectiveness associated with nondifferential misclassification. Based on the assumption that the 1991 observational use rate applies to the 1991 crash population, odds ratios were corrected for seat belt self reporting bias. The corrected odds ratio associated with protection from any degree of injury was 0.723 (95 percent CI 0.685 − 0.763); the corrected odds ratios associated with seat belt use and injuries requiring outpatient emergency care, hospitalization, or fatalities were 0.747 (95 percent CI 0.705 − 0.791), 0.505 (95 percent CI 0.421 − 0.606), and 0.455 (95 percent CI 0.296 − 0.697), respectively. The study results confirm the protective effect of seat belts in motor vehicle crashes and provide a methodology for correcting seat belt effectiveness estimates.

Motor vehicle crashes are a major cause of death and morbidity in the United States, accounting for an estimated cost of $137 billion in 1990. The use of safety restraint devices, including seat belts, shoulder straps, child safety seats, and airbags, has been associated with reduced mortality and morbidity. The total effect of restraint use may be underestimated, however, because previous studies have used patients in trauma centers (1–7). In past studies, victims of motor vehicle crashes were not considered unless they require treatment at the facility where the studies were based. Such studies may underestimate seat belt effectiveness, because they did not include persons who were uninjured.

The Utah Crash Outcome Data Evaluation System (CODES) project was designed to establish a population-based crash data base that includes all victims of reportable motor vehicle crashes in Utah. The data base includes all police crash reports, emergency medical service (EMS) run reports, and files (computerized discharge summaries of medical records) from hospitals and clinics. These hospitals and clinics include outpatient, emergency department, inpatient, and rehabilitation facilities. The 1991 data sources have been linked to a single crash data base using probabilistic linkage, with an estimated linkage efficiency of greater than 80 percent.

Seat belt use information is obtained from police crash reports, and in most instances this is reported by the crash occupant. Because the police officer usually does not witness the accident, uninjured occupants and occupants with minor injuries may be outside the vehicle when the officer is obtaining information concerning seat belt use. The police officer obtains information about seat belt use by asking the occupants. Because seat belt use is mandatory in Utah, crash occupants may report that they used seat belts to avoid a citation and fine. However, seat belt use by more severely injured or killed occupants can be directly assessed by police officers, particularly if extrication is required. Overreporting of seat belt use by uninjured occupants might be expected to overestimate the effectiveness of seat belts.

In Utah, the statewide rate of seat belt use was 46.9 percent as measured by direct observational studies in 1991. In the 1991 CODES data base, however, the reported use rate was 74 percent, suggesting that significant numbers of crash occupants overreport seat belt use to avoid a citation and fine. This is consistent with findings of other investigators, who note significant problems with self-reported seat belt use rates (*8–10*). It is clear that mandatory restraint laws increase self-reported use (*11,12*), but a disparity remains between self-reported rates and direct observational studies (*8,9*). Thus, estimates of seat belt efficacy may be biased.

Seat belt overreporting is a differential misclassification problem, because misclassification is much less likely if the occupant is killed or incapacitated. In addition, occupants who wear seat belts are extremely unlikely to deny seat belt use, because they will incur a citation and fine. Methods have been developed for correcting bias related to exposure variable (*13–15*), confounding covariate (*16–21*), and outcome (*22,23*) misclassification. Corrections of parameter estimates from logistic regression models have been developed (*17,24*) but relate to nondifferential misclassification.

The purpose of this paper is to evaluate the effect of seat belt overreporting (information biased differential misclassification) on the odds ratio and confidence limits relating seat belt use and injury. By using independent observational studies from the same time period, corrected odds ratios may be obtained to provide more reasonable estimates of seat belt effectiveness.

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MATERIALS AND METHODS

Utah 1991 CODES Data Base

The 1991 motor vehicle crash records were obtained from the Utah Department of Transportation, Division of Traffic and Safety. This file includes all crashes reported on public roads in Utah, including all injury accidents and accidents believed associated with property damage over $750. Crash data are obtained by local law enforcement officers who investigate each accident, including all crashes with estimated property damage of $750 or greater. The Utah crash reports include all occupants in a vehicle, including uninjured occupants. In 1991, there were 47,443 accidents involving 74,595 vehicles containing 103,812 occupants. For 7,983 occupants, information concerning restraint use was not available, and these cases were excluded from this study. For this study, only drivers of passenger vehicles and light trucks were included (N = 66,035).

Crash records include extensive information about the circumstances of the accident, including road and weather conditions, lighting conditions, vehicle descriptions, damage descriptions, and driver intentions. Vehicle occupant information includes age, gender, position within the vehicle, use of safety devices, and injury codes.

EMS data records for 1991 were obtained from the Bureau of Emergency Medical Services, Utah Department of Health. Most of these were submitted electronically by pre-hospital providers (>80 percent). All records submitted in hard copy form were reviewed by Utah CODES clerical staff, and incidents involving motor vehicle accidents were added to the computer file. Files containing summary discharge information were obtained from all hospitals in Utah. These files were complete for outpatient emergency department care, inpatient acute care, and rehabilitation care. EMS and hospital files were used to determine whether a crash occupant required on-scene or hospital-based medical care related to the crash.

Linkage of CODES Data Base Files

The CODES data base was constructed by linking the crash file to EMS and hospital files using probabilistic linkage. This methodology is described in detail elsewhere (*25–27*). Successful linkage is related to whether an individual was actually injured, errors in the data sources, and the effectiveness of the algorithm used to achieve the linkage. On the basis of detailed study of the linkage between the crash records and EMS run reports, it is believed that at least 80 percent of individuals who actually required an EMS response, outpatient, or inpatient medical care have been linked in this data base (unpublished observation).

Injury Stratification

Each driver record was classified according to treatment level as follows:

Level 0—No injury indicated on crash report nor linkage to medical care.

Level 1—Injury indicated on crash report but no linkage to an EMS, emergency department, or inpatient record.

Level 2—Injury indicated on crash report and transported by an EMS agency or treated in an emergency department but not hospitalized or killed.

Level 3—Hospitalized but did not die within 30 days of crash.

Level 4—Died within 30 days of crash.

Subsequently, four dependent variables A, B, C, and D were constructed to include populations with increasing levels of injury. Injury variable A was coded as 1 for all drivers with any treatment level above Level 0. Injury variable B was coded as 1 for all drivers with treatment Levels 2, 3, or 4. Injury level C was coded as 1 for all drivers with treatment Levels 3 or 4. Injury level D was coded as 1 for all drivers with treatment Level 4. Variable A is useful for detecting the occurrence of any injury, variables B and C provide information about increasingly severe injuries, and variable D provides information about fatalities. This stratification approach was developed by the seven states participating in CODES projects and staff from NHTSA.

Statistical Analyses

The data were analyzed using a logistic regression model with injury (stratified into Levels A through D as discussed) as the dependent variable. This logistic regression model used was developed by seven states involved in CODES projects and staff at NHTSA. To eliminate differences related to seating position, only drivers were used for this study. The independent variables were seat belt use, whether the vehicle rolled over, whether the crash was a single vehicle, fixed object or multiple vehicle collision, rural versus urban, age, gender, and posted speed limit. A driver was considered belted if the police crash report explicitly reported the use of seat belts or the combination of lap belt and shoulder straps; drivers were considered unbelted if the police crash report explicitly reported nonuse of any of these devices. Drivers for whom belt use was unknown or for whom airbags deployed (N = 43) were excluded from all analyses. In each model there were 43,017 drivers for whom all variables were available.

Stochastic Simulations of Misclassification

As already described, killed or incapacitated individuals (as assessed by the investigating police officer) were assumed to be correctly classified for seat belt use. In addition, reported nonusers were assumed to be correctly classified. All other reported users were considered susceptible to self-reporting bias.

By using a uniform random number generator, fractions f of the potentially misclassified drivers were changed to nonuser status, and the logistic regression model was recomputed with the same variables as described. The step was repeated numerous times for values of f of 0.05, 0.10, 0.15, and 0.25 to assess the variability between simulations for injury level B only. Subsequently, the models were recomputed for all fractions of f between 0 and 1.00 for injury levels A, B, C, and D.

Based on the assumption that the observational rate of 46.7 percent applies to the crash population, the fraction $f = 0.34$ would yield this total rate of use. The logistic models were run with $f = 0.34$ for all 4 injury levels, A through D.

Computer Software

Probabilistic record linkage was performed using Automatcher 2.0 (Matchware, Inc., Silver Spring, Maryland). Data base manipula-

TABLE 1 Seat Belt Use and Sustained of Drivers in 1991 CODES

Seat Belt Use	Total Drivers	Level of Injury None	A	B	C	D
No	19,285	14,888	4,397	3,621	484	86
Yes	46,750 (71%)	40,678 (73%)	6,072 (58%)	5,184 (59%)	288 (37%)	34 (28%)
	66,035	55,566	10,469	8,805	772	120

tions were done with Foxpro 2.0 (Microsoft Corp., Redmond Washington). Logistic regression was done with the logistic procedure (PROC LOGISTIC), and random numbers were generated with the RANUNI function in the SAS statistics system (SAS Institute, Inc., Cary, North Carolina).

RESULTS

The reported use of seat belts by drivers in the Utah CODES data set is shown in Table 1. The table also shows the numbers of drivers, belted and unbelted, who sustained injury at Levels A through D. The overall reported use rate among drivers was 71 percent, which contrasts with the directly measured observational rate of 46.9 percent. There were 55,566 drivers who sustained no injury, and 10,469 drivers sustained some level of injury (injury Level A). As the injury level increases from A through D, the reported seat belt use rate drops from 73 percent (uninjured) to 28 percent (fatalities).

The odds ratio associated with seat belt use varied by injury level. Table 2 shows the full model for injury Level A; the seat belt odds ratio is 0.448 (95 percent CI 0.425 − 0.473). The odds ratios associated with belt use for injury levels B, C, and D were 0.476 (95 percent CI 0.449 − 0.504), 0.203 (95 percent CI 0.170 − 0.241), and 0.148 (95 percent CI 0.097 − 0.226), respectively. Thus, as the level of injury increases, stronger protective effects are seen from the use of seat belts.

Logistic regression was performed with fractions $f = 0.05$, 0.10, 0.15, and 0.25 multiple times, using B level injury as the dependent variable. Figure 1 shows a plot of the resulting odds ratios. It can be seen that, as increasing fractions of reported users are randomized to nonuser status, the odds ratio increases, indicating an attenuation of effect. This confirms the expectation that overreporting exaggerates the effectiveness of seat belts. The figure also demonstrates that repetitive stochastic simulations result in similar odds ratios. For this reason, in subsequent results, single simulations at various fractions f for each injury level are reported.

Logistic regression was then performed with fractions from 0.05 to 1.00 for injury Levels A through D. Figures 2 through 5 show the resulting plots of odds ratios against fractions f. For all injury levels, overreporting clearly causes an exaggeration of seat belt efficacy, though the curves behave somewhat differently. Figure 6 shows all four curves on the same graph.

Note for each injury level that the odds ratio increases rapidly as f approaches 1.00. This is to be expected because of the assumption that all incapacitated or killed individuals were correctly classified with respect to seat belt use. As f approaches 1.00, seat belt use preferentially occurs in incapacitated and killed individuals.

By using observational data to adjust use rates, 15,776 (34.3 percent) reported users must be assumed to be nonusers (again, it is assumed that killed or incapacitated users are correctly classified). Logistic regression models were recomputed for each injury level after randomly switching this number of users to nonusers. The corrected odds ratio associated with protection from any degree of injury was 0.723 (95 percent CI 0.685 − 0.763); the corrected odds ratios associated with seat belt use and injuries requiring outpatient emergency care, hospitalization, or fatalities were 0.747 (95 percent CI 0.705 − 0.791), 0.505 (95 percent CI 0.421 − 0.606), and 0.455 (95 percent CI 0.296 − 0.697), respectively.

DISCUSSION OF RESULTS

In this study, it has been demonstrated that (a) seat belt use reduces injury from motor vehicle crashes with an odds ratio of approximately 0.723, and (b) misclassification of seat belt use exaggerates the apparent effectiveness of seat belt use in preventing injury and

TABLE 2 Result of Unadjusted Logistic Regression Model: Level A is dependent Variable

Variable	Parameter Estimate	Standard Error	Wald Chi-Square	Odds Ratio	95% Confidence Interval
Model Intercept	-1.6009	0.0571	786.43	0.20	0.18 - 0.23
Seat Belt Use	-0.8022	0.0278	830.52	0.45	0.42 - 0.47
Rollover	1.6686	0.0573	848.84	5.31	4.74 - 5.94
SVFO	0.3799	0.0843	20.30	1.46	1.24 - 1.73
SVO	-0.0944	0.0445	4.49	0.91	0.83 - 0.99
MVH	1.162	0.0958	147.01	3.20	2.65 - 3.86
Rural	-0.1946	0.0331	34.66	0.82	0.77 - 0.88
Age	0.00198	0.0008	5.91	1.002	1.000 - 1.004
Male	-0.5061	0.0267	359.41	0.60	0.57 - 0.64
Speed Limit	0.0179	0.0012	218.12	1.018	1.016 - 1.020

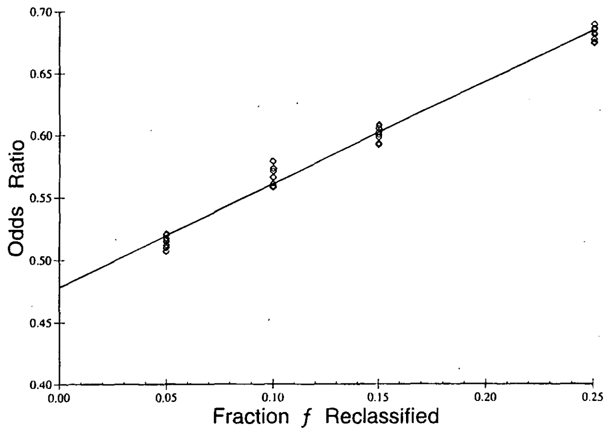

FIGURE 1 Odds ratio for injury Level B associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation, multiple simulations conducted for f = 0.05, 0.10, 0.15, and 0.25.

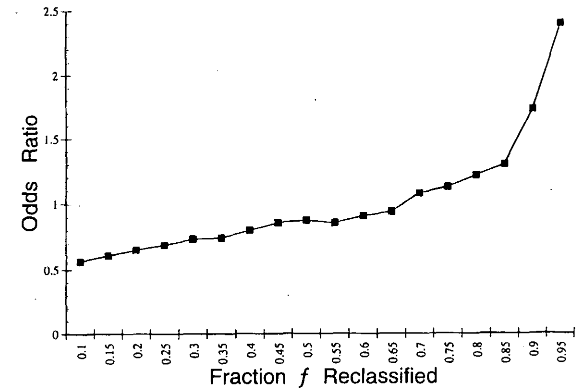

FIGURE 3 Odds ratio for injury Level B associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation.

mortality (to an odds ratio of 0.45 for injury of any type). Statewide observational use data are used to adjust the odds ratios to obtain more reasonable estimates of seat belt efficacy for each level of injury from minor to fatal.

Seat belt use has been known to reduce injury in motor vehicle crashes, but few previous studies have used population-based data (*28*). This is likely the first report of seat belt effectiveness based on a comprehensive, population-based, statewide crash data base that includes all drivers, injured and uninjured. The odds ratio obtained from this population-based study is consistent with previous estimates of seat belt effect (*29*).

The major findings of this study relate to the effect of differential misclassification of seat belt use on the association between seat belt use and noninjury. The observational seat belt use rate in Utah was 46.9 percent, and the expected true value of f was 0.343 in 1991. Assuming different probabilities f of accurate classification, Figures 1 through 4 demonstrate the exaggeration of the protective effect of seat belts with overreporting bias. It is believed that the parameter estimate obtained at f = 0.343 represents a reasonable estimator of the true odds ratio associated with belt use.

It is assumed that police reports accurately classify seat belt use by killed or incapacitated drivers, and adjustments of seat belt classification was restricted to other drivers. Killed or incapacitated drivers are more likely to remain in the vehicle until being extricated by external observers (police, fire fighters, or bystanders), and these external observers are likely to validate the investigating police officer's assessment of belt use. The reported seat belt use rates for killed and incapacitated occupants were 28 and 39 percent, respectively. These rates are well below the statewide observational rate of 46.9 percent. This suggests that there is not a large amount of misclassification in this subset of drivers or the reported use rate would be considerably higher. In contrast, police reports indicated that 73 percent of the uninjured drivers used seat belts, well above the observational rate. In these instances, the drivers are likely to

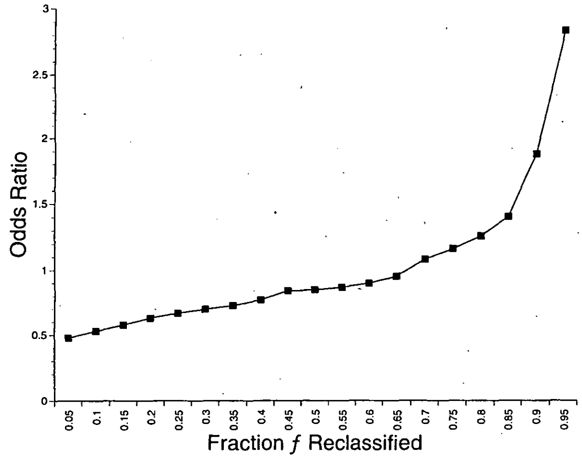

FIGURE 2 Odds ratio for injury Level A associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation.

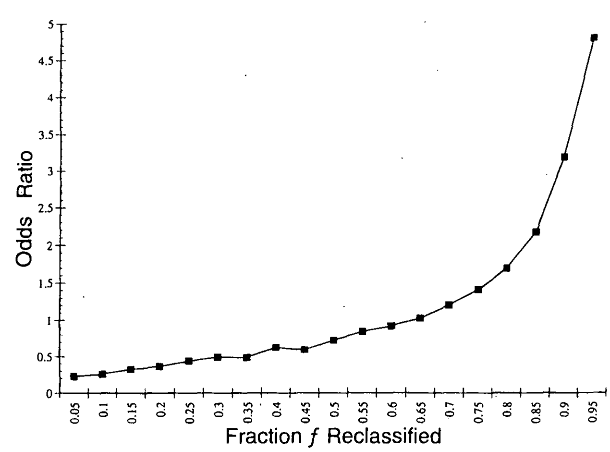

FIGURE 4 Odds ratio for injury Level C associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation.

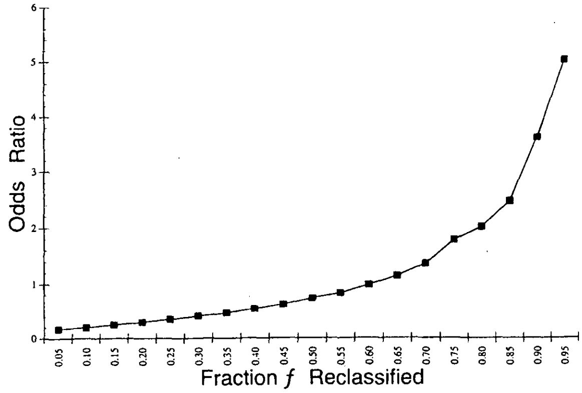

FIGURE 5 Odds ratio for injury Level D associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation.

self-report belt use to the police officer, as such drivers will have already left their vehicle before the arrival of the police officer. These reported use rates (lower than observational) suggest that the police assessment of belt use may be reasonably accurate for killed or incapacitated occupants, but significantly overestimates belt use by uninjured occupants.

To assess this assumption, the simulations were calculated with the assumption that only the dead drivers and nonusers were correctly classified. The odds ratios were lower, not higher, for injury Levels A through C for values for fraction f from 0.05 through 0.40 (the range tested). For fatalities (Level D), odds ratios were higher by no more than 0.06 (value at 0.40 reclassification of drivers). At the reclassification rate of 0.343, assuming incapacitated drivers were as likely to be incorrectly classified as less severely injured drivers, odds ratios were 0.654, 0.687, 0.460, and 0.512 for injury Levels A through D, respectively. Thus, the assumption of correct classification of incapacitated drivers renders a more conservative estimate of seat belt efficacy.

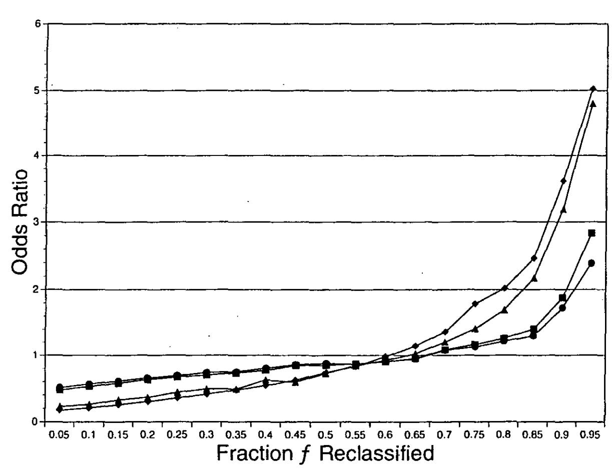

FIGURE 6 Odds ratio for all four injury levels A (square), B (circles), C (triangles), and D (diamonds) associated with seat belt use, function of fraction f of drivers randomly changed from user to nonuser status. Each point represents separate simulation.

Using a single statewide assumption for seat belt misclassification may be criticized, because it is known that males less often use belts than females, usage rates are lower in rural areas, and usage rates are higher on freeways and highways. However, the low variability seen in Figure 1 for repetitive stochastic simulations suggests that the parameter estimates are stable and are much more affected by the relatively large number of drivers who are assumed misclassified. It is not believed that a more sophisticated simulation, stratified for gender, roadways, or rural location, would yield significantly different results from those observed in Figures 2 through 6.

In summary, seat belts significantly reduce injury from motor vehicle crashes. The magnitude of the effect of seat belts on the rate of injury is exaggerated by overreporting seat belt use. Stochastic simulations were used to evaluate the bias associated with misclassification of seat belt use. By using independent observational use data, the original odds ratios were corrected to provide a more reasonable estimate of seat belt efficacy in Utah.

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