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Relative risk of injury and death in ambulances and other emergency vehicles

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Abstract

This study addresses of the impacts of emergency vehicle (ambulances, police cars and fire trucks) occupant seating position, restraint use and vehicle response status on injuries and fatalities. Multi-way frequency and ordinal logistic regression analyses were performed on two large national databases, the National Highway Traffic Safety Administration's Fatality Analysis Reporting System (FARS) and the General Estimates System (GES). One model estimated the relative risk ratios for different levels of injury severity to occupants traveling in ambulances. Restrained ambulance occupants involved in a crash were significantly less likely to be killed or seriously injured than unrestrained occupants. Ambulance rear occupants were significantly more likely to be killed than front-seat occupants. Ambulance occupants traveling non-emergency were more likely than occupants traveling emergency to be killed or severely injured. Unrestrained ambulance occupants, occupants riding in the patient compartment and especially unrestrained occupants riding in the patient compartment were at substantially increased risk of injury and death when involved in a crash. A second model incorporated police cars and fire trucks. In the combined ambulance–fire truck–police car model, the likelihood of an occupant fatality for those involved in a crash was higher for routine responses. Relative to police cars and fire trucks, ambulances experienced the highest percentage of fatal crashes where occupants are killed and the highest percentage of crashes where occupants are injured. Lack of restraint use and/or responding with 'lights and siren' characterized the vast majority of fatalities among fire truck occupants. A third model incorporated non-special use van and passenger car occupants, which otherwise replicated the second model. Our findings suggest that ambulance crewmembers riding in the back and firefighters in any seating position, should be restrained whenever feasible. Family members accompanying ambulance patients should ride in the front-seat of the ambulance.

Keywords: Ambulance crashes; Injuries; Fire trucks; Police cars

1. Introduction

Response to the scene of an emergency and transportation of sick or injured patients to emergency care facilities is a fundamental component of emergency medical services (EMS) systems (Boyd et al., 1983). Though EMS systems have been in place in some localities for more then 20 years, only in the last 10 years have safety researchers begun to study the practices and impacts of emergency vehicle occupant (EVO) behavior including their use of restraints.

Ambulance crashes have received some attention in EMS and other trade media (Elling, 1989; Spivak, 1998; Burns, 1999; LaDuke, 1999) but few peer-reviewed analytical accounts exist. Pirrallo and Swor (1994) examined ambulance crashes in 4 years of Fatality Analysis Reporting System (FARS) data, and provided an overview of the earlier literature, including a series of sporadic government reports. Auerbach et al. (1987) analyzed a very small sample of ambulance crashes in Tennessee. Notably, approximately one-half of vehicle drivers and front-seat occupants were wearing occupant restraints; over one-half of patients lying prone on a stretcher were restrained while only 15% of bench seat patients were wearing restraints and almost all rear-compartment occupants sitting in the 'jump seat' were wearing restraints. Biggers et al. (1996) conducted a retrospective study of 1 year of ambulance crash data from the Houston, Texas fire department. An important finding from this study was that a driver history of prior EMS vehicle crash is a key risk factor for future crashes. Kahn et al. (2001) analyzed 1987–1997 FARS data, focusing on ambulance crashes only and finding that unrestrained rear

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occupants were most at risk for fatal and/or incapacitating injuries. Just over 4% (4.1%) of Schwartz et al.'s (1993) 439 respondents to a New England survey of emergency medical technicians (EMTs) reported that they had been involved in an ambulance collision. Field data monitoring restraint use suggest that there is frequent sub-optimal utilization of the standard restraint systems fitted in ambulance vehicles for both crew and patient occupants (Cook et al., 1991; Larmon et al., 1993; Levick et al., 2000). Gershon et al.'s (1995) review of EMS worker injuries focused mostly on injury type rather than injury cause though motor vehicle collisions were noted as a source of the most serious EMS worker injuries.

Furthermore, while the ambulance transport environment is hazardous due to high-speed driving and other characteristics (Erich, 2001; Kahn et al., 2001), only recently have limited safety crash test studies been conducted (Levick et al., 1998, 2001a,b; Bull et al., 2001) which suggest that there are predictable and preventable risks to the occupants of the ambulance rear-compartment. These studies also demonstrated that failure to use the restraint systems currently fitted to vehicles creates risk for serious injury to both the occupant who is not restrained and can also create hazards for other restrained or unrestrained occupants (Levick et al., 2001c) and suggested that the use of existing restraints and the consideration of head protection could have a major positive impact on occupant protection. Maguire and Porco (1997a) described a two phase intervention that reduced the collision rate in one agency by 50%, involving a new training program and policy changes regarding increased seat belt usage and minimizing driving risk during lights and sirens transport. The same authors found that 100% of the litigation against one EMS agency resulted from transportation related incidents (Maguire and Porco, 1997b).

This paper reports an analysis of two large national databases, the National Highway Traffic Safety Administration's FARS and the General Estimates System (GES). The analysis assesses the impacts of emergency vehicle occupant seating position, restraint use and vehicle response status (emergency versus non-emergency) on EVO injuries and fatalities. In addition, we broaden the traditional scope of EMS vehicles and include fire trucks (FT) and police cars (PC) in this analysis and compare the hazards of travel.

2. Methods

Merged 1988 through 1997 data from the GES and FARS public use files were analyzed using SAS, Release 6.2 (SAS Institute Inc., 1990) and Stata, Version 7.0 (StataCorp, 2001). The number of emergency vehicle occupants experiencing non-fatal injury was estimated from the GES sample of police-reported crashes in the US. GES records injury severity by crash victim on the KABCO scale (National Safety Council, 1990). Police reports in almost every state use KABCO to classify crash victims as K: killed, A: incapacitating injury, B: non-incapacitating injury, C: possible injury, or O: no apparent injury. Regrettably, KABCO ratings are course and tend to be inconsistently coded between states and over time (O'Day, 1993; Miller and Blincoe, 1994; Blincoe et al., 2002). To address KABCO coding inconsistencies and consistent with established practice (Reinfurt et al., 1990; Campbell et al., 1991), we employed a four-step scale, collapsed from KABCO. The scale consisted of: (1) no injury, (2) possible/non-incapacitating injury, (3) incapacitating injury, and (4) fatal injury. The inclusion of GES cases allows us to examine occupant injury and fatality risk in a full range of non-fatal crashes. We substituted actual fatal counts from FARS for the weighted GES fatal cases, with a weight of one assigned to each FARS case, creating a combined weighted data set.

This study is based on a total of 1701, 639, and 1078 GES raw counts for police cars, ambulances and fire department trucks, respectively. For all analyses, the characteristics of EVOs involved in crashes were categorized by type of vehicle (ambulance, fire truck or police vehicle), response mode (emergency versus non-emergency), restraint use, and injury severity. Cases involving ambulances were also analyzed for seating position (front-seat versus other seating positions); inadequate cell sizes prevented this analysis for fire trucks and police cars. Multi-way frequency tables were constructed displaying the results.

Three ordinal logistic regression models were estimated. We chose ordinal logistic regression rather than separate estimation of a series of odds ratios, because ordinal logistic regression simultaneously compares the odd ratios between different levels of injury severity while also simultaneously controlling for multiple risk factors. We used Stata's 7.0 multinomial regression procedure, inputting our injury outcomes as ordinal categories, with "no injury" as the comparison outcome. This allowed us to directly estimate relative risk ratios and is equivalent to using Stata's ordinal logistic regression procedure. Further, Stata 7.0 accommodates complex sample design by computing standard errors via Taylor series approximations The first model estimated the relative risk ratios for different levels of injury severity to EVOs traveling in ambulances. Response mode, seating position and restraint use were introduced as independent variables in the regression. The second model added two other categories of emergency vehicles, police cars and fire trucks, and employed emergency/non-emergency response and restraint use as control variables. Non-special use van and passenger car occupants injured in crashes were added to the third analysis, which otherwise replicated the second model. The binary variable "response mode" was coded "0" to reflect non-emergency travel for all observations pertaining to vans or passenger cars.

3. Results

Table 1 provides an overview of emergency vehicle crashes, showing the number of fatalities and injured and

Table 1
Numbers of crashes and persons involved in emergency vehicles crashes: 1988–1997 (estimated from GES data, based on police report ratings)[a]

	Number of crashes			Fatal injury victims			Non-fatal injury victims			No injuries reported		
	Fatal[b]	Non-fatal	Total	Emergency vehicle occupants	Others	Total	Emergency vehicle occupants	Others	Total	Emergency vehicle occupants	Others	Total
Ambulances	305	36,693	36,998	74	286	360	10,398	12,545	22,943	54,123	38,869	92,992
Fire trucks	166	29,790	29,956	43	152	195	3,660	6,851	10,511	45,831	24,756	70,587
Police cars	1,113	183,871	184,984	228	971	1,199	49,950	45,442	91,392	152,013	179,901	331,914

[a] Cases were discarded where information about at least one of the variables presented in the table was missing.
[b] Fatal injuries counts from FARS data.

non-injured persons involved in crashes. The table also distinguishes between emergency vehicle occupants and occupants of other vehicles and/or pedestrians, a distinction lacking in prior analyses. Although denominator data unavailability prevents the calculation of fatal crashes per million miles driven or fatal crashes per 1000 trips, some other comparisons are possible.

Fatal crashes constituted 0.82% of all ambulance crashes, 0.60% of all police car crashes and 0.55% of all fire truck crashes. There were 0.24 EVO fatalities per fatal ambulance crash, 0.26 EVO fatalities per fatal fire truck crash and 0.20 EVO fatalities per fatal police car crash. So, approximately one in every four fatal ambulance and fire truck crashes and one in every five fatal police car crashes resulted in an EVO fatality. The injury rate per crash is lowest for fire trucks at 0.12 injured EVOs per non-fatal injury crash. There were 0.28 injured EVOs per non-fatal injury ambulance crash and 0.27 injured EVOs per non-fatal injury police crash. Thus, on the basis of simple frequency analysis, ambulances experience the highest percentage of fatal crashes where EVOs are killed and the highest percentage of crashes where EVOs are injured. But, likely due to higher staffing levels, fire trucks experience the highest percentage of occupants killed per fatal crash involving EVO fatalities.

Table 2 highlights the distributional characteristics of injuries and deaths among occupants of ambulances involved in crashes. An estimated total of 37,132 ambulance vehicles were involved in crashes between 1988 and 1997. However, we limited the analysis to 35,966 ambulance vehicles where information on the emergency status of their trip was available. Of 63,985 ambulance occupants estimated to have been involved in these crashes, 61,784 were included in the analysis; the remainder lacked information on injury severity, restraint use, and/or seating position. Table 3 presents summarized exposure data for ambulance EVOs involved in crashes.

Unrestrained occupants riding in positions other than the front-seat (‘in the back’) accounted for 52.11% (37/71) of ambulance occupant fatalities, with restrained occupants riding in the back accounting for an additional 19.71% (14/71). *Thus, 71.82% (51/71) of reported fatalities to ambulance occupants occurred to those riding in the back while only 39.97%* (*307/768*) *of total ambulance occupants in fatal crashes traveled in the rear patient compartment*.

Table 2
The injury severity of ambulance occupants involved in crashes: 1988–1997 (estimated from GES and FARS data, based on police report ratings)[a]

		Injury severity (frequency)				Total occupants	Total vehicles involved in crashes
		No injury	Possible/ non-incapacitating	Incapacitating	Fatal[b]		
Emergency call							23,474
Front-seat	Restrained	27,873 (88.28)	3,305 (10.47)	390 (1.24)	4 (0.01)	31,572	
	Unrestrained	2,479 (79.92)	607 (19.57)	13 (0.42)	3 (0.10)	3,102	
Seated in the back	Restrained	3,071 (86.34)	475 (13.35)	5 (0.14)	6 (0.17)	3,557	
	Unrestrained	3,094 (68.38)	882 (19.49)	531 (11.73)	18 (0.40)	4,525	
Routine trip							12,492
Front-seat	Restrained	11,585 (86.03)	1,562 (11.60)	313 (2.32)	7 (0.05)	13,467	
	Unrestrained	829 (66.16)	198 (15.80)	220 (17.56)	6 (0.48)	1,253	
Seated in the back	Restrained	1,600 (97.92)	26 (1.59)	0 (0.00)	8 (0.49)	1,634	
	Unrestrained	1,717 (64.21)	741 (27.71)	197 (7.37)	19 (0.71)	2,674	
Total		52,248 (84.57)	7,796 (12.62)	1,669 (2.70)	71 (0.11)	61,784	35,966

Values shown in parentheses are percentages.
[a] Cases were discarded where information about at least one of the variables presented in the table was missing.
[b] Fatal injury counts from FARS data.

Table 3
Summarized injury and exposure data for ambulance occupants involved in highway crashes: 1988–1997 (estimated from FARS and GES data, based on police report ratings)[a]

		Ambulance occupants involved in fatal crashes[b]		Ambulance occupants involved in all crashes	
		Fatal injury (%)	Total	Any injury (%)	Total
Emergency call					
Front-seat	Restrained	4 (1.79)	223	3,699 (11.72)	31,572
	Unrestrained	3 (6.52)	46	623 (20.08)	3,102
Seated in the back	Restrained	6 (13.64)	44	486 (13.66)	3,557
	Unrestrained	18 (13.14)	137	1,431 (31.62)	4,525
Routine trip					
Front-seat	Restrained	7 (4.52)	155	1,882 (13.97)	13,467
	Unrestrained	6 (16.22)	37	424 (33.84)	1,253
Seated in the back	Restrained	8 (28.57)	28	34 (2.08)	1,634
	Unrestrained	19 (19.39)	98	957 (35.79)	2,674
Total		71 (9.24)	768	9,536 (15.43)	61,784

[a] Cases were discarded where information about at least one of the variables presented in the table was missing.
[b] Fatal injury counts from FARS cases.

Unrestrained rear occupants also accounted for 43.6% (728/1669) of reported incapacitating injuries while only 11.6% (7199/61,784) of total ambulance occupants rode unrestrained in the rear patient compartment. Of these incapacitating injuries to ambulance rear occupants, 72.9% (531/728) occurred during an emergency run while only 20.0% (12,390/61,784) of total ambulance occupants rode under emergency conditions. Of 2857 non-fatally injured rear occupants of ambulances, 82% (2351) were unrestrained.

Table 4 focuses upon occupants of fire trucks and police cars involved in crashes. Unrestrained occupants in any seating position accounted for 36/45 (80%) of FT fatalities. Over half of all FT fatalities (25/45; 55.5%) occurred during emergency runs. Furthermore, 76% (19/25) of emergency FT fatalities were unrestrained. Overall, 73.2% (2667/3641) of non-fatal FT injuries were incurred during emergency runs.

Analysis of the PC crashes reveals a different picture for occupant crash fatalities. Unrestrained PC occupants in any seating position (79/227) accounted for only 34.8% of PC fatalities (emergency and non-emergency runs combined). In addition more than half (55%; 125/227) of PC fatalities occurred during non-emergency runs. Of 51,086 total non-fatal PC injuries, 48.4% (24,749) occurred during emergency runs. The greater PC crash involvement while engaged in non-emergency driving clearly relates to exposure. Routine

Table 4
The occupant injury severity for fire trucks and police cars involved in crashes: 1988–1997[a]

		Injury severity (frequency)				Total	Vehicles involved in crashes
		No injury	Possible/non-incapacitating	Incapacitating	Fatal[b]		
Fire trucks							
Emergency	Restrained	21,218 (91.01)	1,262 (5.41)	827 (3.55)	6 (0.03)	23,313	17,606
	Unrestrained	7,558 (92.68)	552 (6.77)	26 (0.32)	19 (0.23)	8,155	
Non-emergency	Restrained	12,734 (95.00)	557 (4.16)	108 (0.81)	3 (0.02)	13,402	10,706
	Unrestrained	3,889 (92.31)	183 (4.34)	151 (3.58)	17 (0.40)	4,213	
Total		45,399 (92.49)	2,554 (5.20)	1,087 (2.21)	45 (0.09)	49,083	28,311
Police cars							
Emergency	Restrained	63,755 (75.77)	17,236 (20.49)	3,079 (3.66)	68 (0.08)	84,138	92,775
	Unrestrained	7,321 (62.09)	3,275 (27.78)	1,162 (9.85)	34 (0.29)	11,791	
Non-emergency	Restrained	72,877 (79.99)	16,786 (18.43)	1,359 (1.49)	80 (0.09)	91,102	89,196
	Unrestrained	7,857 (72.08)	2,423 (22.23)	5,766 (5.28)	45 (0.41)	10,900	
Total		151,810 (76.70)	39,720 (20.07)	6,176 (3.12)	227 (0.11)	197,931	177,332

Values shown in parentheses are percentages.
[a] Estimated from GES data, based on police report ratings. Cases were discarded where values for at least one of the variables presented in the table was missing.
[b] Fatal injuries counts from FARS data.

Table 5
Relative risk ratios for injury of ambulance occupants: ordinal regression results controlling for response status, seating position and restraint use

	Relative risk ratios	95% confidence interval		$P > \|t\|$
Possible/moderate injury				
Routine trip	1.089	0.971	1.245	0.051
Seated in the back	1.080	0.966	1.253	0.058
Unrestrained	2.357	1.915	2.945	0.0001
Severe injury				
Routine trip	1.693	1.446	1.973	0.0001
Seated in the back	1.234	1.037	1.436	0.011
Unrestrained	6.493	5.146	7.955	0.0001
Fatal injury				
Routine trip	2.623	1.346	4.857	0.008
Seated in the back	5.323	2.146	10.112	0.0001
Unrestrained	3.765	1.396	6.985	0.009

"No injury" is the comparison outcome.

travel by police cars occupies a greater proportion of police driving time than ambulance and fire truck driving time.

Table 5 presents the results of the ordinal logistic regression model for ambulances. Restrained ambulance occupants involved in a crash had 3.77 ($P < 0.009$) times lower risk of fatality and 6.49 ($P < 0.0001$) times lower risk of incapacitating injury than unrestrained occupants. The risk of a fatality versus no injury for ambulance rear occupants involved in a crash was 5.32 times higher than for front-seat occupants ($P < 0.0001$). Front-seat versus back-seat seating position did not greatly impact the risk of a non-incapacitating injury (RRR = 1.08; NS) but did slightly increase the risk of an incapacitating injury (RRR = 1.23; $P < 0.011$). Another notable finding is that ambulance occupants traveling non-emergency were more likely than occupants traveling emergency to be killed (RRR = 2.62; $P < 0.008$) or severely injured (RRR = 1.69; $P < 0.0001$) if involved in a crash.

Table 6 presents the result of the combined ordinal regression model for ambulances, fire trucks and police cars. In this combined model, non-emergency (routine) response lessened the likelihood of an occupant incurring a non-incapacitating or incapacitating injury versus no injury when involved in a crash. But, the likelihood of an occupant fatality for those involved in a crash was higher for routine responses (RRR = 1.24; $P < 0.036$). Restraint use significantly reduced moderate (RRR = 1.69; $P < 0.003$) and severe (RRR = 3.82; $P < 0.001$) injury and death (RRR = 6.15; $P < 0.0001$) among emergency vehicle occupants involved in crashes. Ambulance occupants were more likely than fire truck occupants, but less likely than police vehicle occupants, to be killed or injured if involved in a crash.

Finally, we attempted to provide a perspective on the comparative risks of travel in non-emergency vehicles of comparable chassis type and, thus, included ordinary passenger cars and vans in analyses for police cars and ambulances, respectively. Relative risk ratios were very similar when van and passenger car crashes were included in the analysis (Table 7). However, reduced fatal injury risk for belt users

Table 6
Relative risk ratios for injury of emergency vehicle occupants: ordinal regression results controlling for response status and restraint use

	Relative risk ratios	95% confidence interval		$P > \|t\|$
Possible/moderate injury				
Ambulance	2.977	2.547	3.823	0.0001
Police car	5.482	4.828	5.973	0.0001
Base: fire trucks				
Routine trip	0.969	0.821	1.131	0.431
Unrestrained	1.691	1.279	1.931	0.003
Severe injury				
Ambulance	1.854	1.221	2.123	0.003
Police car	2.681	2.133	3.011	0.0001
Base: fire trucks				
Routine trip	0.635	0.522	0.875	0.001
Unrestrained	3.822	3.091	4.396	0.0001
Fatal injury				
Ambulance	1.765	1.022	2.511	0.041
Police car	2.311	1.354	3.344	0.001
Base: fire trucks				
Routine trip	1.241	1.081	1.795	0.036
Unrestrained	6.154	4.464	7.974	0.0001

"No injury" is the comparison outcome.

Table 7
Relative risk ratios for injury of occupants of selected vehicles: ordinal regression results controlling for response status and restraint use

	Relative risk ratios	95% confidence interval		$P > \|t\|$
Possible/moderate injury				
Ambulance	2.975	2.541	3.821	0.0001
Police car	5.488	4.801	5.992	0.0001
Vans	3.863	3.533	4.191	0.0001
Passenger cars	5.374	4.493	6.506	0.0001
Base: fire trucks				
Routine trip	0.841	0.754	0.906	0.002
Unrestrained	1.754	1.716	1.819	0.0001
Severe injury				
Ambulance	1.846	1.210	2.132	0.003
Police car	2.711	2.035	3.100	0.0001
Vans	1.863	1.394	2.500	0.002
Passenger cars	2.983	2.692	3.321	0.0001
Base: fire trucks				
Routine trip	0.590	0.460	0.810	0.003
Unrestrained	4.680	4.605	4.810	0.0001
Fatal injury				
Ambulance	1.796	1.015	2.543	0.033
Police car	2.651	1.356	3.711	0.002
Vans	1.519	1.110	2.315	0.011
Passenger cars	3.672	2.074	5.300	0.002
Base: fire trucks				
Routine trip	1.391	1.101	1.796	0.032
Unrestrained	12.831	12.011	13.415	0.0001

"No injury" is the comparison outcome.

was twice as great as in the models examining emergency vehicles only (RRR = 12.83; $P < 0.0001$).

A comparison between the relative risk ratios for ambulance and van occupants reveals that, controlling for emergency use, the former were slightly more likely to suffer a fatal injury compared to no injury (Table 7: respective relative risk ratios: 1.79 ($P < 0.033$) and 1.51 ($P < 0.011$)). Van occupants were more likely than ambulance occupants to suffer minor (Table 7: respective relative risk ratios: 3.86 ($P < 0.0001$) and 2.97 ($P < 0.0001$)) and severe (Table 7: respective relative risk ratios: 1.86 ($P < 0.002$) and 1.84 ($P < 0.003$)) injuries relative to no injury.

Among all occupants in the data set, passenger car occupants had the highest risk of suffering a severe or fatal injury compared to no injury in police-reported crashes. Passenger car occupants were 3.67 times more likely and police vehicle occupants 2.65 times more likely than fire truck occupants to suffer a fatal injury in a crash. These differences, however, are tenuous. They may well result from a greater likelihood or even mandated police reporting of a non-tow-away crash if an emergency vehicle was involved, rather than reflecting a greater injury risk.

4. Discussion

This study builds on previous work by expanding the scope of analysis to include: (1) estimates of non-fatal injury from non-fatal (i.e. GES) crashes; (2) three classes of emergency vehicles—ambulances, fire trucks and police cars; (3) a focus on injuries and fatalities of emergency vehicle occupants; and (4) a comparison of emergency vehicles with other selected vehicle types. Our estimates of the number of ambulance crashes are consistent with those reported from FARS by Pirrallo and Swor (1994) for 1987–1990, Solomon (1999) for 1995, and Kahn et al. (2001) for 1987–1997. While we confirm Kahn et al.'s (2001) findings that unrestrained and rear-seat passengers in ambulances face higher fatality/severe injury rates than restrained front-seat occupants, we believe our relative risk ratios reflect in more detail the dire hazard for unrestrained occupants and patient compartment occupants, as our models control simultaneously response mode, restraint use and seating position.

In addition, our results are consistent with the limited data on restraint use by providers in the rear-compartment. Both Larmon et al.'s (1993) provider survey data and Cook et al.'s (1991) self-reported provider run analyses suggest that prehospital providers believe that traditional restraint systems negatively impacts patient care. Unsafe practices regarding occupant and equipment restraint observed by Levick et al. (2000) suggest that additional education is needed to make EMS providers aware of the potential dangers of these practices. Indeed, protecting one's self while at work is an essential primary injury prevention knowledge and skill area for EMS providers (Garrison et al., 1996).

The results of our ordinal regression analysis of ambulance occupant injuries and fatalities are consistent with prior studies. Unrestrained ambulance occupants, occupants riding in the patient compartment and especially unrestrained occupants riding in the patient compartment are at substantially increased risk of injury and death when involved in a crash. This has now been clearly demonstrated both epidemiologically and also from a biomechanical perspective in recent crash testing (Bull et al., 2001; Levick et al., 2001a,b,c). Regrettably, the FARS data set does not allow us to distinguish between ambulance crew members and patients or accompanying family members. But, regardless of whether a rear patient compartment occupant is a crew member, patient or accompanying family member, the need for using restraints is clear. These findings also suggest that accompanying family members, if present, should ride in the front-seat of the ambulance whenever feasible rather than in the back with the patient.

The results of this study also indicate that restraint practices for these high-risk emergency vehicles need to be reviewed and effective systems need to be designed and appropriately tested under impact conditions. There is a role for the reevaluating of the design of ambulances and other vehicles with a cross disciplinary team including EMS providers, public safety personnel, automotive engineers, and public health researchers. Occupant safety standards for ambulances and other emergency vehicles need to be developed, reviewed and implemented.

Our finding that non-emergency ambulance response travel poses a greater risk of injury and death if involved in a crash may seem counter-intuitive to some and merits further study. There is a growing literature on the virtues and pitfalls of emergency response with sirens and warning lights (see Brown et al., 2000 and references therein). Perhaps, blaring sirens and flashing lights secondarily serve to protect ambulance crews through their warning functions. Our finding suggests that pending further study, it may be premature to conclude that emergency response is a 'myth of out-of-hospital medicine' as has been suggested by one author (Pirrallo, 1996).

Our analysis of fire truck crashes clearly leads to two conclusions: (1) unrestrained fire fighters are at high risk for injury and/or death when involved in a crash; and (2) emergency response is especially hazardous for firefighters. Ensuring that crews are suitably restrained prior to response is likely one way to mitigate the hazard.

Finally, the results of our analysis of police vehicle crash injury and fatality data reveal a different picture. Neither lack of restraint use nor emergency response seems extraordinarily useful in explaining PC occupant injury and fatality. In addition, we did not analyze seating position in police cars because there were too few reports of rear-seat travel in crash-involved vehicles. Further studies are needed to explore and describe other factors contributing to police vehicle occupant injuries and fatalities.

The present study has several limitations; (1) Inadequate cell sizes prevent examining variations in occupant injury by collision-type, collision location (e.g. intersection versus other), 'first harmful' event or 'most harmful' event; (2) Entry into our FARS analysis required that a vehicle be identified (reasonable certainty) and subsequently coded (less certainty) as an ambulance rather than a light truck or van. Furthermore, the data and possibly the case counts are not available to conduct an analysis by ambulance type (I, II, or III) and chassis type; and (3) The United States Fire Administration (USFA) has been collecting supplemental data on firefighter injury deaths in moving vehicles since 1994.Comparisons of FARS and USFA counts of these events reveal comparable mean numbers of deaths per year, but in 3 of the 4 years for which both data sets are available, the counts do not agree. This suggests that the actual counts may be higher than revealed by either data set and that USFA and FARS might consider regularly exchanging and comparing these data.

Finally, FARS- and GES-based studies of ambulance occupant injuries likely undercount the true occurrence of these events. The abrupt application of ambulance brakes to avoid a sudden hazard in the roadway may produce sufficient force to throw unrestrained crew-members against compartment walls and cause injury. However, if the driver was successful in avoiding the hazard, a crash might not occur and the report of injury, while available from Worker's Compensation or EMS provider injury and insurance records, is otherwise lost to analysis.

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