SEVERE TRAFFIC INJURIES ACROSS CENTRAL MIDWESTERN STATES: COMPARISON OF STATE DATA TO REGIONAL ESTIMATES

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ABSTRACT

The objective of this study was to compare crash characteristics across four central Midwestern states (Iowa, Kansas, Missouri, and Nebraska). Complete crash data was obtained for six years (2001-2006) with variables identified at the national level used as the explanatory factors in binary logit models predicting the odds of a driver sustaining a severe injury. Results were then compared to the national estimates for the same region based on the General Estimates System (GES). General findings across the four states indicate higher likelihoods of severe injuries based on demographics (female drivers, older drivers), behavior (disuse of seat belt, alcohol or drug use) and crash and road type (head-on crashes, rural roads, dry surfaces, high speed roads). Many of these findings are consistent with previous studies. However, the magnitudes of these associations are not the same across the states with some associations not even identified as significant (e.g., adverse weather was a significant indicator in only one state). At the regional level, represented by 12 Midwestern states, different results were obtained for rural crashes. The outcomes raise concerns on whether the segmentation by geographical region for national crash estimates is appropriate. However, misreporting and underreporting of key variables (e.g., distraction factors) can also constrain the comparisons across states and may also be related to the design of crash reporting forms. Findings from this study underscore the need for improvements and standardization of crash reporting procedures to facilitate crash injury analysis.

Keywords: injury severity, crash data, General Estimates System (GES), Midwestern crashes, rural areas, crash type

INTRODUCTION

Many traffic regulations and countermeasures are aimed at reducing the rate of driver fatalities and injuries. However, traffic safety is still a major concern in the United States. US crash data from the year 2008 show that over 37,000 people were killed and about 2.5 million were injured from motor vehicle crashes (NHTSA, 2009). In one study, highway crashes were estimated to be responsible for about 3.2% of medical cost in the US, and more than 14% of medical cost for drivers 15-24 years old (Miller, Lestina, & Spicer, 1998). These statistics underscore the importance of research on traffic-related injuries. Although several studies have provided some insights on the driver, vehicle, and road and environmental factors associated with these motor vehicle crash injuries and fatalities (e.g., Bedard, Guyatt, Stones, & Hirdes, 2002; Connor, Norton, Ameratunga, & Jackson, 2004; Evans & Frick, 1994; Huelke & Compton, 1995; Kim, Nitz, Richardson, & Li, 1995; O'Donnell & Connor, 1996), there are differences that exist across states and many of these differences correspond to the data used as well as the analytical technique employed.

Driver characteristics related to elevated crash risks include age and experience (Kweon & Kockelman, 2003; Zhang, Fraser, Lindsay, Clarke, & Mao, 1998), weather conditions (Khattak, Kantor, & Council, 1998; Khattak & Knapp, 2001), alcohol impairment (Keall, Frith, & Patterson, 2004; Zador, Krawchuk, & Voas, 2000), and driver distraction (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006; Neyens & Boyle, 2008; Violanti, 1998). However, the patterns of injury risk do differ across regions. For example, a model of injury severity based on data from Hawaii showed no significance differences for age and gender (Kim, et al., 1995), while studies on Wisconsin (Tavris, Kuhn, & Layde, 2001) and Iowa do reveal differences in age and gender. In the case of Iowa, the estimates at the state level also differed from the national estimates (Hill & Boyle, 2005). These findings underscore the impact of aggregation on the observed patterns. In other words, a model based on national data may not be able to capture patterns specific to the state or region.

The Midwestern states in the US have some similarities including many rural roads and sparsely populated areas. These rural areas also contribute to a large proportion of crash fatalities in the US (NHTSA, 2008b). A study on four Midwestern states of Kansas, Nebraska, South Dakota, and North Dakota showed that there is an inverse relationship between motor vehicle crash fatality rates and population density (Muelleman & Mueller, 1996). That is, the more sparse the population in these rural areas, the higher the fatality rates. A 5-mph increase in roadway speed limit increases the rate of fatalities and injuries (Baum, Lund, & Wells, 1989; Renski, Khattak, & Council, 1999). Although many studies tend to group this region into one cluster, there may be differences between these states with respect to traffic patterns.

The present study examines different factors surrounding traffic crashes and the severity of driver injuries within four Midwestern states: Iowa, Kansas, Missouri, and Nebraska. Each state is examined individually and then compared to national estimates for the Midwestern region. It is hypothesized that the injury trends will be similar to those previously observed in other studies using Midwestern states, but the magnitude of such associations may differ. Comparisons will then be made to the representative sample at the region level of all 12 Midwestern states, extracted from the General Estimates System (GES) (NHTSA, 2008a). Conclusions and policy recommendations are made based on the results of the analyses and comparisons.

METHODS

Data Sources

Data for this study was obtained from the Departments of Transportation and Roads of Iowa, Kansas, Missouri, and Nebraska. The four databases contained information of crashes for the years 2001 to 2006. Each state's database was formatted differently and hence, standardized and reformatted to facilitate comparisons. The usable crash records available for analysis encompassed 78.33% of Iowa, 84.49% of Kansas, 85.68% of Missouri, and 70.53% of Nebraska's reported crashes.

A model of the Midwestern region of the US based on data from the National Automotive Sampling System (NASS)-GES for the same years (2001 to 2006) was then used as a comparison to the individual findings (NHTSA, 2008a). The GES data is a stratified sample of crashes weighted to represent national crash patterns. The GES obtains its data from a nationally representative probability sample that is extracted from police accident reports (PARs). The sampling from PARs is accomplished in three stages: 1) sampling of geographic areas which provides the Primary Sampling Units (PSUs), 2) sampling of police jurisdiction within each PSU, and 3) selection of crashes within the sampled police jurisdictions (NHTSA, 2005).

Injury Level Classification in Crash Data

The classification of injury level in crash reports is based on the KABCO scale, which was introduced by the National Safety Council in the late 1960s (Compton, 2005). This rating system, also used in GES (NHTSA, 2005), categorize occupant injuries into five groups: fatal (K), incapacitating (A), non-incapacitating (B), possible injuries or complaint of pain (C), and not injured (O). In addition, categories such as 'unknown' and 'not reported' are included for some states since discerning the level of injury may not always be possible. All four states examined in this study employ the KABCO scale; although minor word choice differences do exist among the crash reporting systems (see Table 1).

Table 1. Detailed KABCO Injury Categories in Crash Databases

Crash database		**Iowa**	**Kansas**	**Missouri**	**Nebraska**	**GES national sampled data**
KABCO injury levels	**K**	Fatal	Fatal injury	Fatal	Fatal	Fatal injury
	A	Incapacitating	Disabled (incapacitating)	Disabling injury	Disabling	Incapacitating injury
	B	Non-incapacitating	Injury, not incapacitating	Evident injury (not disabling)	Visible	Non-incapacitating injury
	C	Possible	Possible injury	Probable injury (not apparent)	Possible	Possible injury
	O	Uninjured	Not injured	Not apparent	No injury	No injury
Augmenting categories		Unknown	Unknown	Unknown	-	Died prior to crash
		Not reported	-	-	-	Unknown if injured
		-	-	-	-	-

Explanatory Variables

Separate models were developed for each state to examine the factors that may increase the likelihood of a severe injury. The injury severity levels were grouped into two general categories of 'severe' (including codes K and A) and 'non-severe' injuries (including codes B, C, and O) and examined using binary logit models developed with SAS (Statistical Analysis System) version 9.1 and the CATMOD procedure (PROC CATMOD). Multinomial logit regression models have been extensively used in the context of occupant injury severity in the literature of traffic safety to provide comparisons between levels of outcome variables with no apparent ordering (Awadzi, Classen, Hall, Duncan, & Garvan, 2008; Bedard, et al., 2002; Khorashadi, Niemeier, Shankar, & Mannering, 2005; Watt, Purdie, Roche, & McClure, 2006). Binary logit regression, as a special form of multinomial logit regression, is used in this study, due to the dichotomous nature of the dependent variable (injury severity).

The goal of this study was to compare relevant factors across states. Hence, the explanatory variables examined included those already well established in the literature and the estimates were adjusted for seat belt use and air bag deployment. Drivers were categorized into three age groups: 24 years old and younger (younger drivers), aged between 25 and 65 (reference group), and drivers older than 65 (older drivers) as similarly done in other studies (Farmer, Braver, & Mitter, 1997; Khattak, et al., 1998; Zhang, et al., 1998). Weather conditions were divided into two categories; normal and adverse weather. Adverse weather category encompassed situations where rain, snow, freezing rain, fog/smoke, mist, sleet, severe winds, blowing sand/soil/dirt, or combinations of these conditions were present. If none of the above conditions were present, then weather was labeled as normal. Roadway speed limit was set up into three groups: less than 35 mph, between 35 and 55 mph, and higher than 55 mph. For this factor, drivers involved in crashes on roads with the second category of speed limit were considered as the reference group.

Five types of crashes were also examined; rear-end, head-on, angular, sideswipe, and single-vehicle crashes. Angular, rear-end, sideswipe, and head-on crashes are the four categories of 'collision with motor vehicle in transport' used by US DOT, while single-vehicle crashes correspond to 'collisions with fixed object' and 'collision with object not fixed' (NHTSA, 2009). In addition to crash type, the (initial) crash point of impact was included for states whose crash database supported this variable (i.e., Iowa and Nebraska).

Two driver-related factors were also of particular interest given the abundance of literature demonstrating increase crash risk: driver distraction and blood-alcohol content (BAC). However, the crash databases did not include sufficient information regarding these two factors for the years examined. More specifically, the proportion of crashes that included any details about the distraction-related factors encompass only 1.27% in Iowa, 1.33% in Kansas, 1.18% in Missouri, and 0.81% in Nebraska. Surprisingly, driver BAC information was not available in any of the states' databases either. Those states that did include this variable had a large proportion of non-reporting (e.g., about 51% of Iowa crashes with drivers under the influence of alcohol lacked BAC level). Considering these limitations, only the more general factor of 'being under the influence of alcohol or drugs' (yes or no) was used in the analyses.

RESULTS

State Level

All states' databases included most of the variables needed for this analysis. The Iowa crash database included all variables of interest. Kansas did not have sufficient information regarding point of impact, while Nebraska lacked data on air bag deployment. Missouri did not have information on drug use, air bag deployment, and point of impact. All models fitted well (all *p*-values of likelihood ratios = 1.00) and the significance level was set to 0.0001.

There were similar demographic patterns across the four states (Table 2). Drivers' mean age ranged from 36.64 (in Nebraska) to 37.90 (in Missouri). The proportion of female drivers ranged from 43.23 (Kansas) to 45.09 % (Nebraska). Among crash types, angular and rear-end crashes were the most common in each of the five databases, comprising 65-85% of crashes (Table 3).

Table 2. Descriptive Statistics of States' Crash Data

State	Number of crashes	Mean age (SD)	Gender proportions (%)		Proportion using seat belt (%)	Proportion under the influence of alcohol/drug (%)
			Male	Female		
Iowa	370,428	37.85 (18.46)	55.82	44.18	57.82	4.01
Kansas	598,070	36.66 (17.34)	56.77	43.23	83.84	5.68
Missouri	1,465,219	37.90 (17.91)	56.43	43.57	82.25	2.91
Nebraska	271,445	36.64 (17.23)	54.91	45.09	79.10	1.52

Table 3. Frequencies of Crash Types in Crash Databases

Crash Type	Iowa		Kansas		Missouri		Nebraska		GES (Midwest)	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Angular	137,687	37.17	196,864	32.92	487,583	33.28	104,099	38.35	4,424,740	36.11
Rear-end	114,150	30.82	190,377	31.83	573,904	39.17	125,349	46.18	4,446,780	36.29
Sideswipe	48,569	13.11	42,100	7.04	145,999	9.96	39,316	14.48	1,062,281	8.67
Head-on	8,951	2.42	11,005	1.84	41,184	2.81	2,053	0.76	239,021	1.95
Single-vehicle	48,569	16.49	157,724	26.37	216,549	14.78	628	0.23	2,079,440	16.97
All crashes	370,428		598,070		1,465,219		271,445		12,252,262*	

*Based on weighted observations

Driver Characteristics and Behaviors and In-vehicle Circumstances

The binary logit model (Table 4) revealed that female drivers were more susceptible to serious injuries in all Midwestern states with similar estimates between Iowa and Kansas (AORs = 1.07 and 1.08, respectively) and between Missouri and Nebraska (AORs = 1.21 and 1.24, respectively). With respect to driver age, younger drivers (younger than 25) were less likely to sustain serious injuries when compared to the middle-aged group (aged 25-65). Older drivers were more likely to be severely injured. There was also an age and gender interaction in

Missouri only, with young females being less likely to sustain severe injuries compared to middle-aged male drivers (AOR = 0.96).

Passengers were shown to have a protective effect in Iowa and Kansas, with drivers being less severely injured driving with passengers when compared to driving alone. In contrast, drivers with passengers in Missouri were more likely to sustain severe injuries. No significant association was observed between injury severity and passengers in Nebraska.

As expected, there was a higher likelihood of a severe injury when the driver did not use a seat belt and this was consistently observed in all four states with Nebraska and Missouri being more similar in odds (AORs = 2.70 and 2.74, respectively) and Iowa and Kansas having higher odds ratio (3.59 and 4.24, respectively). Air bag deployment data was available in Iowa and Kansas only, and drivers in these two states were more likely to be severely injured with an airbag deployment. For all state models, drivers under the influence of alcohol or drug were significantly more likely to sustain severe injuries compared to sober drivers. The magnitude of this effect varied slightly from 1.32 (Kansas) to 1.74 (Nebraska).

<u>Crash Types and Points of Impact</u>

The odds of sustaining severe injuries were higher for head-on crashes when compared to rear-end crashes, ranged from 3.18 in Iowa to 4.92 in Kansas. Drivers in sideswipes were less likely to sustain severe injuries in all four states, with quite similar odds ratios (from 0.38 to 0.50). Observations for single-vehicle crashes were consistent for Iowa and Missouri, indicating higher likelihoods of serious injuries (AORs = 1.29 and 1.93, in Iowa and Missouri, respectively). However, the odds of having severe injuries were not significantly different between single-vehicle and rear-end crashes in Kansas and Nebraska. No significant difference was observed between angular and rear-end crashes in any of the states, in terms of severe injury odds. Drivers in crashes that impacted the driver side were 1.16 and 1.82 times more likely to sustain severe injuries compared to those whose vehicles were impacted on the rear side, in Iowa and Nebraska, respectively. No other significant differences were observed with respect to crash types and points of impact.

Table 4. State Models for the Likelihood of Severe Injuries

	Iowa				Kansas			
Parameter	**Estimate**	**SE**	χ^2	**Adjusted OR**	**Estimate**	**SE**	χ^2	**Adjusted OR**
Intercept	-2.21	0.03	4012.3	0.11	-3.33	0.04	5816.6	0.04
Head-on crashes	1.16	0.04	1049.6	3.18	1.59	0.04	1517.2	4.92
Angular crashes	0.07	0.02	ns	1.08	0.10	0.03	ns	1.10
Sideswipes	-0.70	0.04	346.8	0.5	-0.89	0.05	271.1	0.41
Single-vehicle crashes	0.26	0.02	114.9	1.29	0.09	0.03	ns.	1.10
Rural settings	0.54	0.02	1097.4	1.71	0.65	0.03	575.1	1.92
Female drivers	0.07	0.01	22.9	1.07	0.08	0.01	43.2	1.08
Age < 25	-0.36	0.02	346.3	0.7	-0.26	0.02	180.5	0.77
Age > 65	0.40	0.02	279.7	1.49	0.33	0.03	164.7	1.39
Passenger(s) present in the car	-0.10	0.01	64.0	0.9	-0.07	0.01	30.3	0.93
Adverse weather	0.02	0.02	ns	1.02	0.05	0.03	ns	1.05
No daylight	-0.07	0.01	23.8	0.94	-0.09	0.01	42.4	0.92
Non-dry surface	-0.17	0.02	87.8	0.85	-0.18	0.02	52.9	0.84
Under influence of alcohol/drug	0.50	0.02	753.7	1.64	0.28	0.02	250.9	1.32
No seat belt in use	1.28	0.02	2813.8	3.59	1.44	0.03	2105.1	4.24
Air bag deployed	0.76	0.02	1254.0	2.13	0.27	0.03	115.7	1.32
Speed limit < 35 mph	-0.48	0.03	361.5	0.62	-0.93	0.03	1348.6	0.39
Speed limit > 55 mph	0.29	0.03	110.5	1.34	0.79	0.03	837.6	2.20
Point of impact: front	-0.03	0.02	ns	0.97	-	-	-	-
Point of impact: driver side	0.15	0.03	30.0	1.16	-	-	-	-
Point of impact: passenger side	-0.11	0.03	ns	0.9	-	-	-	-
Point of impact: top/under	0.10	0.06	ns	1.1	-	-	-	-
Head-on crashes in rural settings	0.23	0.03	44.6	1.26	0.39	0.05	57.1	1.48
Angular crashes in rural settings	0.04	0.02	ns	1.04	0.01	0.04	ns	1.01
Sideswipes in rural settings	0.07	0.04	ns	1.07	0.14	0.07	ns	1.15
Single-vehicle crashes in rural settings	-0.33	0.02	217.9	0.72	-0.73	0.03	546.5	0.48
Female drivers younger than 25	-	-	-	-	-	-	-	-
Female drivers older than 65	-	-	-	-	-	-	-	-
Likelihood ratio (initial-convergence)	19894.74				9361.05			
Number of observations	370,428				598,070			

NOTE: All parameters are significant at $p \leq 0.0001$ unless otherwise noted (ns). For variables not found statistically significant, no contrast estimate is reported.

Table 4 Continued

	Missouri				Nebraska			
Parameter	**Estimate**	**SE**	χ^2	**Adjusted OR**	**Estimate**	**SE**	χ^2	**Adjusted OR**
Intercept	-3.03	0.02	18146.8	0.05	-2.69	0.10	738.2	0.07
Head-on crashes	1.24	0.02	2759.4	3.44	1.45	0.09	277.6	4.26
Angular crashes	-0.06	0.02	ns	0.95	0.18	0.06	ns	1.20
Sideswipes	-0.96	0.04	641.7	0.38	-0.68	0.07	90.4	0.50
Single-vehicle crashes	0.66	0.02	1529.0	1.93	-0.22	0.23	ns	0.80
Rural settings	0.94	0.01	4211.4	2.55	0.76	0.02	1325.1	2.15
Female drivers	0.19	0.01	618.1	1.21	0.21	0.02	143.4	1.24
Age < 25	-0.21	0.01	420.0	0.81	-0.31	0.03	120.1	0.73
Age > 65	0.25	0.01	336.2	1.28	0.35	0.04	101.0	1.42
Passenger(s) present in the car	0.49	0.01	4606.2	1.64	-0.01	0.02	ns	0.99
Adverse weather	-0.06	0.01	20.1	0.94	0.07	0.04	ns	1.07
No daylight	0.00	0.01	ns	1.00	0.11	0.02	26.9	1.11
Non-dry surface	-0.09	0.01	78.6	0.92	-0.21	0.03	51.6	0.81
Under influence of alcohol	0.31	0.01	927.4	1.36	0.56	0.04	226.3	1.74
No seat belt in use	1.01	0.02	4020.4	2.74	0.99	0.04	550.3	2.70
Air bag deployed	-	-	-	-	-	-	-	-
Speed limit < 35 mph	-0.59	0.01	1833.5	0.56	-0.54	0.04	191.6	0.58
Speed limit > 55 mph	0.47	0.01	1969.0	1.60	0.74	0.04	351.8	2.09
Point of impact: front	-	-	-	-	-0.08	0.07	ns	0.92
Point of impact: driver side	-	-	-	-	0.60	0.07	68.8	1.82
Point of impact: passenger side	-	-	-	-	0.15	0.08	ns	1.16
Point of impact: top/under	-	-	-	-	0.01	0.24	ns	1.01
Head-on crashes in rural settings	0.19	0.03	48.8	1.20	-	-	-	-
Angular crashes in rural settings	-0.12	0.02	39.5	0.88	-	-	-	-
Sideswipes in rural settings	0.20	0.04	22.1	1.22	-	-	-	-
Single-vehicle crashes in rural settings	-0.19	0.02	109.7	0.83	-	-	-	-
Female drivers younger than 25	-0.05	0.01	21.0	0.96	-	-	-	-
Female drivers older than 65	0.04	0.01	ns	1.04	-	-	-	-
Likelihood ratio (initial-convergence)	14845.97				7880.31			
Number of observations	1,465,219				271,445			

Environmental Conditions

Drivers involved in crashes in rural settings were more likely to sustain severe injuries when compared to those having crashes in urban areas, across all four state models. The odds ratios ranged from 1.71 (in Iowa) to 2.55 (in Missouri). Non-dry surfaces were associated with lower likelihoods of severe crashes in all four states considered; i.e., the odds of sustaining severe injuries on non-dry surfaces were between 0.81 (for Nebraska) and 0.92 (for Missouri) compared to dry surfaces. The interaction between crash location and crash type was significant in Iowa, Kansas, and Missouri. Drivers involved in head-on crashes in rural settings were more likely to be severely injured (AORs = 1.26, 1.48, and 1.20 in Iowa, Kansas, and Missouri, respectively), compared to those involved in rear-end crashes in urban settings. By contrast, drivers in single-vehicle crashes in rural settings were less likely to sustain severe injuries (AORs = 0.72, 0.48, and 0.83 in Iowa, Kansas, and Missouri, respectively). In Missouri, two additional contrasts were significant as well; driver in angular crashes in rural settings were 0.88 times less likely and those in sideswipes were 1.22 times more likely to have severe injuries.

Findings regarding lighting conditions were not consistent across the states. In Iowa and Kansas, drivers were slightly less likely to sustain severe injuries in crashes occurring in non-daylight situations, i.e., during night, dawn, or dusk (AORs = 0.94 and 0.92, respectively). In Nebraska, contrary to Iowa and Kansas, the odds of sustaining severe injuries were higher in daylight hours (AOR = 1.11). The Missouri model showed no significant association between lighting and injury severity. Weather condition at the time of crash was a significant factor only in Missouri, where drivers were slightly less likely to be severely injured in crashes occurring in adverse weather conditions (AOR = 0.94).

The likelihood of driver's sustaining severe injuries also increased on roads with higher posted speed limits. The odds ratios for severe injuries on roads with lower speed limits (less than 35 mph) compared to the reference speed limit (35-55 mph) were very similar for Iowa, Missouri, and Nebraska (0.62, 0.56, and 0.58, respectively), while Kansas revealed a slightly lower odds ratio (0.39). For roads with higher speed limits, the odds ratios ranged from 1.34 in Iowa to 2.20 in Kansas.

Comparisons across States

There were some common and consistent findings across all four Midwestern states for various driver characteristics (gender, age, alcohol and drug use, and seat belt use), as well as environmental conditions including surface condition, posted speed limit, and rural/urban settings. However, differences were observed for crash type. The outcomes revealed that single-vehicle crashes significantly impacted the likelihood of a severe injury in Iowa and Missouri, but in Kansas and Nebraska, there was no difference between single-vehicle and rear-end crashes in the odds of a severe injury.

Similarly, the interaction between crash type and location (rural/urban) was significant for all states but Nebraska. The interaction between age and gender, on the other hand, was only significant in Missouri. Result pertaining to weather condition showed significant differences only in Missouri. Lighting condition results showed a similar pattern in Iowa and Kansas, the opposite pattern in Nebraska, and no significance in Missouri. Passengers were found to be similarly associated with the odds of severe injuries to the driver in Iowa and Kansas, with the opposite direction of results observed in Missouri, and contrast insignificance in Nebraska.

Point of impact information was only available for Iowa and Nebraska, where it produced patterns in the same direction (although different in magnitude). Air bag deployment information was only available in Iowa and Nebraska. Here again, results indicated associations in the same direction but different magnitude.

The common findings across the four states suggest some crash injury pattern homogeneity; however, there were also a number of disparities pointed out above. These findings motivate developing a Midwestern crash injury severity model, extract driver injury patterns from it, and compare them to the four state models to assess the extent to which sampled crash databases can describe injury patterns across the region.

Regional Level

Midwestern crash data used in the injury severity model included 97,070 weighted records, representing 12,252,262 crashes. The binary logit model developed had a good fit with the likelihood ratio *p*-value equal to 1.00. Results obtained from the Midwestern states' injury model are summarized in Table 5 (only estimates pertaining to significant factors are included in the table) and reported in the remainder of this section. These results are applicable to the whole Midwestern region of the US, consisting of 12 states (i.e., Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, North Dakota, South Dakota, Nebraska, Iowa, Missouri, and Kansas), based on the sampling regions used by the National Automotive Sampling System (NASS) in collecting the GES data (NHTSA, 2005), and not any or all of the four states considered for this study in particular. The goal of this analysis is to find the extent to which findings based on the states' crash databases and a sampled crash database, i.e., GES, agree in terms of associations between conditions surrounding a crash and the level of injuries sustained by drivers.

<u>Driver Characteristics and Behaviors and In-vehicle Circumstances</u>

Driver's gender was found significant in the model developed for the Midwest based on the GES data; female drivers were 8% more susceptible to severe injuries than males (AOR = 1.08). Driver age was a significant factor as well. Younger drivers were less likely to be severely injured while older drivers were more likely to sustain severe injuries when compared to those aged between 25 and 65 (AORs = 0.71 and 1.47, respectively). The interaction between age and gender was also significant; younger female drivers were less and female drivers aged more than 65 were more likely to be severely injured in car crashes (AORs = 0.95 and 1.03).

Restraint use was also significant. The likelihood of having severe injuries for drivers with no restraint was 5.29 times more than drivers wearing seatbelts. As expected, air bag deployment was associated with severe injuries (AOR = 3.42). Drivers under the influence of alcohol or drug were found to be 2.47 times more likely to have severe injuries compared to sober drivers. Conversely, drivers with passengers in their cars where slightly less likely to be seriously injured compared to drivers who traveled alone (AOR = 0.97).

Crash Types and Points of Impact

Drivers involved in head-on crashes were 2.82 times more likely to have severe injuries compared to those in rear-end crashes. Drivers in single-vehicle and angular crashes were also more likely to sustain severe injuries (AORs = 1.86 and 1.10, respectively). As expected, sideswipes were mainly associated with minor or no injuries (AOR = 0.34).

Vehicles impacted on the driver side were more likely to be severely injured compared to those with vehicles impacted on the back (AOR = 1.82). Other areas of the vehicle (i.e., front, passenger side, top, or undercarriage) were associated with lower likelihoods of severe injuries, compared to rear of the vehicle (AORs = 0.92, 0.90, and 0.75, respectively).

Environmental Conditions

Midwestern crashes model revealed that drivers were more likely to sustain severe injuries in crashes occurring in non-daylight (i.e., dark, dawn, or dusk) conditions compared to crashes during daylight hours (AOR = 1.08). By contrast, crashes on non-dry surfaces (e.g., snow covered, icy, wet, dirty) were associated with less likelihood of severe injuries (AOR = 0.82). Weather conditions (i.e., adverse versus normal weather) were found insignificant.

Crashes in rural settings were significantly less injurious for drivers (AOR = 0.92). The interaction between crash type and rural or urban setting in which the crash had occurred was also significant; drivers who had been in angular and single-vehicle crashes in rural settings were more likely to be seriously injured (AORs = 1.08 and 1.09), and those in sideswipes were less likely to have severe injuries (AOR = 0.71). This interaction was insignificant for head-on crashes.

Roadway speed limit was found significant; drivers involved in crashes on roadways with speed limits lower than 35 mph were 0.55 times less likely to have severe injuries compared to those in crashes on roads with a 35 to 55 mph speed limit. Crashes on roadways with posted speed limits higher than 55 mph were 1.47 times more likely to result in severe injuries than those on roadways with speed limits between 35 and 55 mph.

State and Regional Level Comparison

The goal of comparing the state outcomes with the sampled data collected as part of GES is to assess the capability of gaining insights on the Midwestern states when aggregated to the region level. It should be noted that the GES data for the Midwest does cover 12 states within the region. The additional eight Midwestern states are Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, North Dakota, and South Dakota. GES does not provide data at the state level and as such, it was not possible to isolate the four states for which the individual analyses had been done.

Table 5. Regional Model for the Likelihood of Severe Injuries

Parameter	Estimate	SE	χ^2	Adjusted OR
Intercept	-3.36	0.017	37015.7	0.03
Head-on crashes	1.04	0.011	8500.3	2.82
Angular crashes	0.09	0.007	197.7	1.1
Sideswipes	-1.09	0.017	4261.2	0.34
Single-vehicle crashes	0.62	0.007	7491.5	1.86
Rural settings	-0.09	0.005	286.3	0.92
Female drivers	0.07	0.004	310.8	1.08
Age < 25	-0.34	0.006	3820.6	0.71
Age > 65	0.38	0.007	2809.7	1.47
Passenger(s) present in the car	-0.03	0.004	62.5	0.97
Adverse weather	0.01	0.006	1.1	1.01
No daylight	0.08	0.003	480.6	1.08
Non-dry surface	-0.19	0.005	1423.6	0.82
Under influence of alcohol/drug	0.91	0.023	1557.2	2.47
No restraint in use	1.67	0.009	32223.5	5.29
Air bag deployed	1.23	0.005	62029.3	3.42
Speed limit < 35 mph	-0.59	0.006	10441.2	0.55
Speed limit > 55 mph	0.39	0.007	2872.1	1.47
Point of impact: front	-0.09	0.009	93.5	0.92
Point of impact: driver side	0.6	0.01	3307.1	1.82
Point of impact: passenger side	-0.11	0.011	97.3	0.9
Point of impact: top/under	-0.29	0.032	82	0.75
Head-on crashes in rural settings	-0.03	0.011	9.1	0.97
Angular crashes in rural settings	0.08	0.006	151.1	1.08
Sideswipes in rural settings	-0.35	0.016	465.6	0.71
Single-vehicle crashes in rural settings	0.08	0.007	155.5	1.09
Female drivers aged less than 25	-0.05	0.005	89.9	0.95
Female drivers aged more than 65	0.03	0.007	17.8	1.03
Likelihood ratio (initial-convergence)			438835.9	
Number of unweighted observations				97,070
Number of weighted observations				12,252,262

The odds ratios (and corresponding confidence intervals) for the parameter estimates common across the four states and at the regional level are listed in Table 6. The greatest similarities are for driver age and roadway surface condition, where the odds ratios estimated by the four state models are close and the odds ratios calculated by the GES-based model fall in their range. The same pattern is evident for the contrast between lower (less than 35 mph) and reference (35-55 mph) speed limits. For driver gender, the odds ratio calculated for the contrast between female and male drivers (1.08) is equal to the odds ratio for the same contrast in Kansas and very close to that of Iowa (1.07); however, the value of the odds ratio for this contrast is higher for Missouri and Nebraska (1.21 and 1.24, respectively). For higher speed limits (above 55 mph), the odds of sustaining severe injuries is 1.47 based on the GES model which is between the odds ratios calculated for the states of Iowa and Missouri (1.34 and 1.60, respectively). However, the odds ratios estimated for the same contrast in Kansas and Nebraska are considerably higher (2.20 and 2.09).

In many cases, there was general agreement among the state models and the GES-based model on the association between certain levels of a factor (e.g., no restraint in use by driver) and severe injuries, but as expected, the strength of such association was not always similar. For crash type, the likelihood of a head-on crash sustaining greater injuries when compared injuries associated with rear-end crashes (OR = 2.82) was lower at the regional level than at the state level. The same is observed for sideswipes where the odds ratio of sustaining serious injuries (0.34) is lower at the regional level than at the individual states' models (range of 0.38 to 0.50). On the contrary, the GES-based odds ratios for alcohol and drug use and restraint use are higher than the highest odds ratios found in the individual states' models, indicating stronger associations between being under the influence of alcohol or drugs and having no restraint in use, and sustaining severe injuries by drivers. No confidence interval overlap is evident between the GES-based Midwestern model and the individual states models.

The air bag deployment factor could only be incorporated in the models of Iowa and Kansas due to the unavailability of precise data for the other two states. The odds of having serious injuries for cases in which air bags had been deployed were 3.42 times the cases without air bag deployment, based on the GES Midwestern model. Iowa and Kansas models showed weaker incompatible contrasts; i.e., odds ratios of 2.13 and 1.32, respectively. The comparison of confidence intervals revealed no overlap between the results of the three models. Therefore, the observations for air bag deployment yield no consensus for the Midwestern states considered in this study.

As noted earlier, point of impact was only available in for Iowa and Nebraska. The contrast between driver side and rear side of the vehicle was significant in predicting driver's injury severity for both states, indicating higher likelihoods of serious injuries for drivers whose cars were impacted on driver side versus those involved in crashes in which rear of the car was affected (odds ratios of 1.16 for Iowa and 1.82 for Nebraska). While the pattern observed in Nebraska was exactly the same as that calculated based on the GES data (with a wider confidence intervals for Nebraska), the contrast was smaller for Iowa, depicting a weaker difference between the levels of injury sustained by drivers for the two points of impact.

For rural versus urban settings, the directions of findings were completely opposite. The GES Midwestern model depicted slightly lower likelihoods of severe injuries for drivers in crashes occurring in rural settings (odds ratio of 0.92), whereas all the individual state models predicted higher likelihoods of such injuries in rural regions compared to urban settings, with odds ratios in the range of 1.71 to 2.55. This is the only contradiction between the states data and GES data-based models.

Table 6. Parameters Related to the Findings across the Four Midwestern States and the Region

Parameter		Logit Models (AOR and Confidence Intervals)				
		Iowa	Kansas	Missouri	Nebraska	Midwest
Crash Type	Head-on crashes	3.18	4.92	3.44	4.26	2.82
		(2.83, 3.58)	(4.30, 5.63)	(3.18, 3.72)	(3.20, 5.67)	(2.72, 2.92)
	Sideswipes	0.50	0.41	0.38	0.50	0.34
		(0.44, 0.56)	(0.34, 0.49)	(0.34, 0.43)	(0.40, .64)	(0.32, 0.36)
(compared to rear-end)						
Rural setting (compared to urban)		1.71	1.92	2.55	2.15	0.92
		(1.62, 1.80)	(1.75, 2.10)	(2.43, 2.67)	(2.00, 2.30)	(0.90, 0.93)
Females (compared to males)		1.07	1.08	1.21	1.24	1.08
		(1.02, 1.12)	(1.04, 1.13)	(1.18, 1.25)	(1.17, 1.31)	(1.06, 1.09)
Driver age	< 25 years	0.70	0.77	0.81	0.73	0.71
		(0.65, 0.74)	(0.73, 0.82)	(0.79, 0.84)	(0.66, 0.80)	(0.70, 0.72)
	> 65 years	1.49	1.39	1.28	1.42	1.47
		(1.38, 1.61)	(1.27, 1.51)	(1.23, 1.34)	(1.27, 1.60)	(1.43, 1.50)
(compared to 25-65)						
Non-dry surface (compared to dry surface)		0.85	0.84	0.92	0.81	0.82
		(080, 0.90)	(0.77, 0.91)	(0.89, 0.95)	(0.74, 0.89)	(0.81, 0.84)
Alcohol/ drug impairment (compared to sober driving)		1.64	1.32	1.36	1.74	2.47
		(1.55, 1.74)	(1.25, 1.40)	(1.31, 1.40)	(1.54, 1.97)	(2.29, 2.67)
No restraint in use (compared to seat belt in use)		3.59	4.24	2.74	2.70	5.29
		(3.31, 3.88)	(3.82, 4.70)	(2.60, 2.89)	(2.35, 3.10)	(5.13, 5.45)
Speed limit	< 35 mph	0.62	0.39	0.56	0.58	0.55
		(0.57, 0.67)	(0.36, 0.43)	(0.53, 0.58)	(0.51, 0.66)	(0.54, 0.56)
	> 55 mph	1.34	2.20	1.60	2.09	1.47
		(1.22, 1.47)	(2.01, 2.41)	(1.55, 1.66)	(1.84, 2.38)	(1.44, 1.51)
(compared to 35-55 mph)						
Air bag deployed (compared to no air bag deployment)		2.13	1.32	n/a	n/a	3.42
		(1.99, 2.29)	(1.21, 1.43)			(3.36, 3.47)
Point of impact: Driver side (compared to rear side)		1.16	n/a	n/a	1.82	1.82
		(1.06, 1.27)			(1.44, 2.31)	(1.76, 1.89)

DISCUSSION

The goal of this paper was to investigate the factors associated with severe (fatal or incapacitating) injuries sustained by drivers in crashes, with a focus on the Midwestern states in the central part of the US. The majority of the findings from each state were consistent with the literature. For example, our findings showed that females and older drivers were more susceptible to severe injuries in car crashes and this is observed in the majority of previous studies (Bedard, et al., 2002; O'Donnell & Connor, 1996). Seat belt use had even greater effectiveness at the state level when compared to estimates from other studies (Bedard, et al., 2002; Evans, 1993; Malliaris, Digges, & DeBlois, 1995; Martin, Crandall, & Pilkey, 2000).

Alcohol and drug use is another factor that has consistently been observed to increase the likelihood of severe injuries (Evans, 1990; Evans & Frick, 1993; Keall, et al., 2004; Mayhew, Donelson, Beirness, & Simpson, 1986; Sjogren, Bjornstig, Eriksson, Ohman, & Solarz, 1997; Zador, et al., 2000). Head-on crashes were associated with the highest odds of sustaining severe injuries and this is consistent with the findings of O'Donnell and Connor (1996).

There were differences that are worth noting. The four Midwestern states were not consistent with respect to crash type, with severe injuries more likely in single-vehicle crashes compared to rear-end crashes in Iowa and Missouri, and equally likely in the two crash types in Kansas and Nebraska. Crashes in rural settings were more likely to cause severe injuries than those occurring in urban crashes at the state level. However, the opposite was observed at the regional level, underscoring the impact of potential information loss when aggregating to the general region. Although this study had crash data for only four states, it clearly demonstrates that differences do exist from the state to regional level. Population distribution differences and geographical properties of different regions of the Midwest are influential in the disparity observed, even though the same modeling technique was used in all the models developed.

The four studied States may also have more rural characteristics when compared to other Midwestern states such as Illinois, Michigan, and even Indiana, with much larger metropolitan areas (e.g., Chicago, Detroit, and Indianapolis). Research has shown that the differences in injury patterns in rural and urban settings is mainly due to the variations in availability of trauma care systems and distance from these facilities (Bentham, 1986; Brodsky & Hakkert, 1988). Therefore, with more crashes occurring in areas with access to advanced medical facilities, these differences may lessen with other factors influencing urban crashes, e.g., roadway geometry, type of vehicle, distractions, etc., playing a larger role in the severity of injuries.

There are many data quality issues with using crash data at the state and national level related to underreporting, misclassification, and omitted data. At the national level, crashes are sampled and reported from four regions: Northwest, Midwest, South, and West. However, since the goal has been to develop nationally representative crashes, crashes have not been identified and weighted for individual states. As such, it was not possible to compare results of the models based on individual states' data with results of similar models based on the GES data for each state, and investigate the level of conformity of the patterns found based on the sampled crash data with those found based on complete crash databases.

State crash databases used in this study had several shortcomings, which resulted in the need to exclude many crash records from the data used in statistical analyses, and also lack of some of the crash or driver attributes in some state models (i.e., point of impact in Kansas, air bag deployment, point of impact, and drug use in Missouri, and air bag deployment in Nebraska). The same problem was identified by Ghazizadeh and Boyle (2009) in their study of driver distraction.

Crash factors were not as comprehensive at the state level as initially expected, with Missouri having perhaps the highest level of reporting in many factors. Specific examination of the crash forms for the years studied provide some insights on the relatively low numbers for some of these driver-related variables. In all four states, there was no specific call out for the various types of distraction, but instead all four states had 'contributing circumstances' as a variable with distraction or inattention as a category. The Missouri and Nebraska forms did include distraction as a check box, whereas in Iowa and Kansas, categories of distraction were entered under a generic contributing circumstances area. Hence, standardization of information across states can provide researchers better outcomes for comparing across states and this can also have implications for outcomes at the regional level.

Another issue related to non-reporting and misclassification of conditions surrounding a crash is the reliability of the estimates. Cummings (2002) compared estimates of fatalities based on seat belt use, for police-reported data and data based on trained crash investigators' reports and found no substantial difference. Guo, Eskridge, Christensen, Qu, and Safranek (2007) showed that misclassifications of seat belt and alcohol use in Nebraska biased the odds ratio estimates of injury only slightly. These studies demonstrate that even though the crash reporting systems might not be ideal, estimates driven based on the compiled crash databases are still reliable and have valuable insights to offer.

Future studies should examine the differences in rural/urban areas and crash type over a larger portion of the Midwest, and over a longer time period. More complete datasets can also allow researchers to incorporate a larger number of factors in injury severity models with better control on nuisance factors, e.g., driver distraction and BAC for which accurate and reliable information is often missing on crash records. Another path future research may move along is exploring the underlying reasons for the disparity observed in injury trends in different states. Research in this direction can help provide insights for more effective countermeasures to guide safer driver behaviors and driving environments.

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REFERENCES

Awadzi, K. D., Classen, S., Hall, A., Duncan, R. P., & Garvan, C. W. (2008). Predictors of injury among younger and older adults in fatal motor vehicle crashes. *Accident Analysis & Prevention, 40*(6), 1804-1810.

Baum, H. M., Lund, A. K., & Wells, J. K. (1989). The mortality consequences of raising the speed limit to 65 mph on rural interstates. *American Journal of Public Health, 79*(10), 1392-1395.

Bedard, M., Guyatt, G. H., Stones, M. J., & Hirdes, J. P. (2002). The independent contribution of driver, crash, and vehicle characteristics to driver fatalities. *Accident Analysis & Prevention, 34*(6), 717-727.

Bentham, G. (1986). Proximity to hospital and mortality from motor vehicle traffic accidents. *Social Science & Medicine (1982), 23*(10), 1021.

Brodsky, H., & Hakkert, A. S. (1988). Risk of a road accident in rainy weather. *accident Analysis & Prevention, 20*(3), 161-176.

Compton, C. P. (2005). Injury severity codes: A comparison of police injury codes and medical outcomes as determined by NASS CDS Investigators. *Journal of Safety Research, 36*(5), 483-484.

Connor, J., Norton, R., Ameratunga, S., & Jackson, R. (2004). The Contribution of Alcohol to Serious Car Crash Injuries. *Epidemiology, 15*(3), 337.

Cummings, P. (2002). Association of seat belt use with death: a comparison of estimates based on data from police and estimates based on data from trained crash investigators. *Injury Prevention, 8*(4), 338-341.

Evans, L. (1990). The fraction of traffic fatalities attributable to alcohol. *Accident Analysis & Prevention, 22*(6), 587-602.

Evans, L. (1993). Restraint effectiveness, occupant ejection from cars, and fatality reductions. *Accident Analysis & Prevention, 22*, 167-175.

Evans, L., & Frick, M. C. (1993). Alcohol's effect on fatality risk from a physical insult. *Journal of Studies on Alcohol, 54*(4), 441-449.

Evans, L., & Frick, M. C. (1994). Car mass and fatality risk: has the relationship changed? *American Journal of Public Health, 84*(1), 33-36.

Farmer, C. M., Braver, E. R., & Mitter, E. L. (1997). Two-vehicle side impact crashes: The relationship of vehicle and crash characteristics to injury severity. *Accident Analysis & Prevention, 29*(3), 399-406.

Ghazizadeh, M., & Boyle, L. N. (2009). Influence of driver distractions on the likelihood of rear-end, angular, and single-vehicle crashes in Missouri. *Transportation Research Record, 2138*, 1-5.

Guo, H., Eskridge, K. M., Christensen, D., Qu, M., & Safranek, T. (2007). Statistical adjustment for misclassification of seat belt and alcohol use in the analysis of motor vehicle accident data. *Accident Analysis & Prevention, 39*(1), 117-124.

Hill, J. D., & Boyle, L. N. (2005). *Analyzing Severe Injury Risk for Crashes Nationally and Within Iowa.* Paper presented at the Mid-Continent Transportation Research Symposium, Ames, Iowa.

Huelke, D. F., & Compton, C. P. (1995). The effects of seat belts on injury severity of front and rear seat occupants in the same frontal crash. *Accident Analysis & Prevention, 27*(6), 835-838.

Keall, M. D., Frith, W. J., & Patterson, T. L. (2004). The influence of alcohol, age and number of passengers on the night-time risk of driver fatal injury in New Zealand. *Accident Analysis & Prevention, 36*(1), 49-61.

Khattak, A. J., Kantor, P., & Council, F. M. (1998). Role of Adverse Weather in Key Crash Types on Limited-Access: Roadways Implications for Advanced Weather Systems. *Transportation Research Record, 1621*(-1), 10-19.

Khattak, A. J., & Knapp, K. K. (2001). Interstate Highway Crash Injuries During Winter Snow and Nonsnow Events. *Transportation Research Record, 1746*(-1), 30-36.

Khorashadi, A., Niemeier, D., Shankar, V., & Mannering, F. (2005). Differences in rural and urban driver-injury severities in accidents involving large-trucks: An exploratory analysis. *Accident Analysis & Prevention, 37*(5), 910-921.

Kim, K., Nitz, L., Richardson, J., & Li, L. (1995). Personal and behavioral predictors of automobile crash and injury severity. *Accident Analysis & Prevention, 27*(4), 469-481.

Klauer, S. G., Dingus, T. A., Neale, V. L., Sudweeks, J. D., & Ramsey, D. J. (2006). The impact of driver inattention on near-crash/crash risk: an analysis using the 100-car naturalistic driving study data. Washington, DC: NHTSA.

Kweon, Y. J., & Kockelman, K. M. (2003). Overall injury risk to different drivers: combining exposure, frequency, and severity models. *Accident Analysis & Prevention, 35*(4), 441-450.

Malliaris, A. C., Digges, K. H., & DeBlois, J. H. (1995). Evaluation of Airbag Field Performance. *SAE transactions, 104*(6), 1513-1534.

Martin, P. G., Crandall, J. R., & Pilkey, W. D. (2000). Injury trends of passenger car drivers in frontal crashes in the USA. *Accident Analysis & Prevention, 32*(4), 541-557.

Mayhew, D. R., Donelson, A. C., Beirness, D. J., & Simpson, H. M. (1986). Youth, alcohol and relative risk of crash involvement. *Accident Analysis & Prevention, 18*(4), 273-287.

Miller, T. R., Lestina, D. C., & Spicer, R. S. (1998). Highway crash costs in the United States by driver age, blood alcohol level, victim age, and restraint use. *Accident Analysis & Prevention, 30*(2), 137-150.

Muelleman, R. L., & Mueller, K. (1996). Fatal Motor Vehicle Crashes: Variations of Crash Characteristics within Rural Regions of Different Population Densities. *The Journal of Trauma: Injury, Infection, and Critical Care, 41*(2), 315.

Neyens, D. M., & Boyle, L. N. (2008). The influence of driver distraction on the severity of injuries sustained by teenage drivers and their passengers. *Accident Analysis & Prevention, 40*(1), 254-259.

NHTSA. (2005). National Automotive Sampling System (NASS) General Estimates System (GES): Analytical user's manual 1988-2005. Washington, DC: U.S Department of Transportation.

NHTSA. (2008a). General Estimates System (GES) 2001-2006 Retrieved June 2008, from ftp://ftp.nhtsa.dot.gov/GES

NHTSA. (2008b). Traffic Safety Facts 2007 Data: Rural/Urban Comparison. Washington, DC: U.S. Department of Tranportation.

NHTSA. (2009). Traffic Safety Facts 2008: A compilation of motor vehicle crash data from the fatality analysis reporting system and the general estimates system. Washington, DC: U.S Department of Transportation.

O'Donnell, C. J., & Connor, D. H. (1996). Predicting the severity of motor vehicle accident injuries using models of ordered multiple choice. *Accident Analysis & Prevention, 28*(6), 739-753.

Renski, H., Khattak, A. J., & Council, F. M. (1999). Effect of speed limit increases on crash injury severity: Analysis of single-vehicle crashes on North Carolina Interstate highways. *Transportation Research Record, 1665*(1), 100-108.

Sjogren, H., Bjornstig, U., Eriksson, A., Ohman, U., & Solarz, A. (1997). Drug and Alcohol Use Among Injured Motor Vehicle Drivers in Sweden: Prevalence, Driver, Crash, and Injury Characteristics. *Alcoholism: Clinical and Experimental Research, 21*(6), 968-973.

Tavris, D. R., Kuhn, E. M., & Layde, P. M. (2001). Age and gender patterns in motor vehicle crash injuries: importance of type of crash and occupant role. *Accident Analysis & Prevention, 33*(2), 167-172.

Violanti, J. M. (1998). Cellular phones and fatal traffic collisions. *Accident Analysis & Prevention, 30*(4), 519-524.

Watt, K., Purdie, D. M., Roche, A. M., & McClure, R. (2006). Injury severity: role of alcohol, substance use and risk-taking. *Emergency Medicine Australasia, 18*(2), 108-117.

Zador, P. L., Krawchuk, S. A., & Voas, R. B. (2000). Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data. *Journal of Studies on Alcohol, 61*(3), 387-395.

Zhang, J., Fraser, S., Lindsay, J., Clarke, K., & Mao, Y. (1998). Age-specific patterns of factors related to fatal motor vehicle traffic crashes focus on young and elderly drivers. *Public Health, 112*(5), 289-295.