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# Determinants of Older Driver Safety From a Socioecological Perspective

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Older driver safety is a complex phenomenon, extending beyond the person level to multiple system characteristics, such as epidemiologic, environment, and policy. Studying multiple factors in older driver safety requires the use of an integrated socioecological approach. In a cross-sectional design, we used a public health model and the 2003 General Estimates System database to determine main risk factors and their measures of association in the presence or absence of injury among older adults involved in motor vehicle accidents. Compared to the findings of the existing literature, participants demonstrated similar *person-level* crash-related injury characteristics. However, the socioecological model elucidated the importance of *environment-level* and *vehicle-level* factors as significant determinants of older driver safety. **Key words:** *cross-sectional study*, *General Estimates System (GES)*, *logistic regression*, *national database*, *older driver safety*, *Precede-Proceed Model of Health Promotion*, *secondary analysis*

OLDER DRIVER SAFETY is a complex phenomenon that extends beyond the person level to multiple system characteristics, such as epidemiologic, environment, and policy. There are approximately 27.5 million licensed drivers aged 65 and older in the United States.[1] In 2001, except for very young drivers and on the basis of miles driven, they had the highest rates of fatal crashes.[1] The numbers of licensed older drivers are increasing, with more than 40 million projected by 2020.[2]

Unlike other age groups with safety concerns such as speeding, alcohol abuse, and reckless driving, older driver crashes often stem from physical, sensory, or cognitive declines as a result of the normal aging process. Person-level factors such as comorbid medical conditions and associated medication use[3–5] are further complicated by vehicle technologies not designed to accommodate their associated frailty and fragility,[6,7] and roadways often not designed to accommodate the age-related changes such as vision or cognitive declines.[8] Moreover, among states, we do not have consensus in policy or regulations to keep older drivers on or off the road safely.[9,10] Studying older driver safety issues, and considering the multiple factors impacting safety in driving, therefore requires an integrated socioecological approach. The Precede-Proceed Model of Health Promotion, a socioecological planning model,[11] addresses quality of life; health; epidemiology; behavior; environment; predisposing, reinforcing, and enabling

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factors; health education; and administration. As such, this model can be effectively applied to study the complexities of older driver safety.

Several predictors for safe driving among the elderly exist in the current literature; however, the interplay of these variables has received little attention. One way of examining the relationships of various factors on the outcome is using secondary analysis of existing databases. Secondary analysis, a valid mode of inquiry, is often used in disciplines such as public health. This method is cost-effective, decreases subject burden, is useful for exploring new areas of research,[12] allows for the study of large populations over time, and is useful for the assessment of subpopulations.[13] Secondary data, used to supplement data, are useful in research where it is impractical or unethical to do a prospective study.[14] Although national data sets afford many benefits, the researcher is responsible for selecting the most appropriate database with great care and consideration to ensure rigor in the research.

Pitfalls of these databases, including bias, confounding, missing data, erroneous data, and use of measurement tools with potentially questionable psychometric properties, must be recognized.[15] During the selection process the researcher must consider the methodology, types of missing data, limitations, and conclusions of the original data set.[16] Nevertheless, when chosen carefully, existing databases provide a rich opportunity to perform secondary analysis on existing risk factors and may show how these risk factors relate to an outcome. National databases, popular for studying older driver safety issues in the United States, include the Fatality Analysis Reporting System (FARS), General Estimates System (GES), National Household Travel Survey (NHTS), and the Crashworthiness Data System (CDS).

## PURPOSE

Using the Precede-Proceed Model of Health Promotion and a national database, this study retrospectively determined the main risk factors and, in the presence or absence of injury (dependent variable), their measures of association among those 65 years and older who were involved in a motor vehicle accident in the United States.

## METHODS

### Population

We consulted with scientists, scholars, experts, and a representative from the National Highway Transportation Safety Administration (NHTSA) for the analysis of secondary databases and older driver studies. A conversation with Y. Gorina, MS (March 10, 2005), and e-mail correspondences and telephone conversations with A. Dellinger, PhD (July 2004), and J. Eberhard, PhD (March 2005), helped us to identify 14 federal databases pertaining to older adult drivers.

### Sample

After approval from the Institutional Review Board of the University of Florida, we refined our database selection to those who could best answer our research question.

Specific inclusion criteria for database selection were an older driver involved in unsafe motor vehicle driving (eg, crash, near crash, crash with or without fatalities, and injuries) in the United States and the socioecological factors related to the driver, the environment, and the vehicle. We used our a priori list of exposure variables to pilot test the databases.[17] After a first elimination, 4 databases that met these criteria—FARS, GES, NHTS, and the CDS—were included for further testing. Our final selection was the 2003 GES database from the Department of Transportation for its rigor, utility, accessibility, merging qualities, and number and quality of socioecological variables. The 2003 GES data, selected from a nationally representative probability sample, yielded 6.4 million police-reported crashes annually resulting in injury, fatality, and/or major property damage.[18]

## Design

We used a cross-sectional study to examine data from the 2003 GES database.

## Procedure

We downloaded the 2003 GES record-level data ASCI files from the public Web site of NHTSA[18] and converted these files to an SPSS file using the *SPSS* computer program, Version 13 (SPSS, Inc, Chicago, Ill). Using the crash case number, we merged three 2003 GES record-level files; *accident*, *vehicle*, and *person* ($n = 151{,}482$). We included all the motor vehicle crashes ($n = 10{,}421$) in 2003 that resulted in fatalities, injuries, and/or property damage for people 65 years and older. After merging these files, the data were stored in a secure password-protected computer and server network. We inspected the 2003 GES database for data precision and accuracy. Using the data dictionary, we examined each of the items to ensure its fit with our conceptual model (Precede-Proceed Model of Health Promotion). Selections were based on the number of missing data, fit to the conceptual model, and meaningfulness of the item to the outcome variable.[19]

To further limit the confounding effects, we excluded crashes involving adults who were not driving a motor vehicle at the time of the crash. After these exclusions, our sample yielded 7847 crashes involving older drivers.

## Measurement

Explanatory variables were chosen in accordance with the findings of a systematic literature review examining older driver safety.[20] These variables were then compared to the items present in the 2003 GES database. Those that appeared, or showed relevance to the findings of the systematic literature review, were selected for further analysis. Twenty-eight explanatory variables representing the person (eg, age and gender), environment (eg, interstate highway, work zone, or weather), and vehicle (eg, precrash or initial point of impact) domains were selected (Table 1). Twenty-five of these were categorical variables and 3 numerical variables. Some of these variables (eg, precrash events, violations charged, and visual circumstances) had 16 or more levels. These refined levels did not contribute useful information to our research question. Some variables were therefore collapsed, yielding cells with adequate frequencies for a meaningful inferential anlaysis. In addition, we excluded categories such as "unknown" or "not coded" in the analysis. Fourteen of the 28 variables used in our analyses were imputed (Table 1).

The outcome variable, injury severity (imputed), yielded 6 categories. This study was not concerned with the detailed levels of injury severity, but rather with identifying the person-level, environment-level, and vehicle-level factors that were associated with injury. To operationalize unsafe driving, the 6 categories were collapsed into 1 outcome with 2 levels: injury yes/no.

## Analyses

Through the functions of *SPSS*, we performed a descriptive analysis, a bivariate analysis, and a binary logistic regression analysis. Using bivariate analysis, we examined the relationships of the explanatory variables with the outcome variable (injuries). We used the $\chi^2$ test for analyzing categorical data and the Wilcoxon rank sum test for analyzing numerical data (skewed distribution). After examining the data in the bivariate analysis, we excluded variables that yielded more than 10% missing data. For the remaining data, we created dummy variables. The reference category in each case was selected as the item level most associated with the outcome. For example, for the item road surface conditions, "wet" conditions, versus dry conditions, was selected as the referent category. Using the *SPSS* "enter" property, we keyed the variables into a binary logistic regression model.

**Table 1.** Samples (person-level, environment-level, and vehicle-level variables) chosen from the 2003 GES database by type and imputation

| Variable | Categorical | Numerical | Imputed |
|---|---|---|---|
| *Person-level variables* | | | |
| Age | | × | × |
| Gender | × | | × |
| Driver drinking in vehicle | × | | × |
| Police-reported drug involvement | × | | |
| Use of vehicle restraints | × | | |
| Travel speed | | × | |
| Speed-related accident | × | | |
| Visual circumstances | × | | |
| Driver distractions | × | | |
| Violations charged | × | | × |
| Physical impairment | × | | |
| *Environment-level variables* | | | |
| Interstate highway | × | | |
| Work zone/construction | × | | |
| Junction/interchange | × | | × |
| Horizontal road alignment | × | | × |
| Vertical road alignment | × | | × |
| Traffic control | × | | × |
| Road surface condition | × | | × |
| Weather condition | × | | × |
| Light conditions | × | | × |
| Hour of crash | | × | × |
| Day of the week | | | × |
| Month of the year | × | | |
| *Vehicle-level factors* | | | |
| Vehicle-contributing factors | × | | |
| Initial point of impact | × | | × |
| Vehicle-level injury severity | × | | |
| Precrash events | × | | |
| Presence of airbag | × | | |

## RESULTS

### Descriptive statistics

Table 2 shows that the mean age of participants ($N = 7847$) was 73.26 (SD = 0.08), with 4850 (61.8%) being male drivers. Of these, 274 (3.3%) had physical impairments. The majority of the crashes, 6457 of 7847 (82.3%), took place under daylight conditions, with 6255 of 6530 (95.8%) drivers wearing some type of a restraint device and 1876 of 3492 (59.7%) crashes occurring while traveling at low speeds (between 1 and 40 miles per hour). Only 146 of 7847 (1.9%) crashes occurred at a construction or work zone area, and 6927 of 7689 (90.1%) crashes did not have vehicle-contributing factors (eg faulty tires, brake, or steering system). Regarding the location of the crashes, 2749 of 7847 (34.9%) were intersection related, with 194 of 7847 (2.5%) related to driver-alcohol involvement. Concerning the number of violations charged to the drivers, 683 of 7541 (9.1%) were related to failure to yield right of way, and surprisingly,

**Table 2.** Description of older drivers in the 2003 GES database*

| | |
|---|---|
| Age ($n = 7847$) | 73.26 (6.71)† |
| Gender ($n = 7847$) | |
| Male | 4850 (61.8) |
| Female | 2997 (38.2) |
| Physical impairment ($n = 7847$) | |
| None | 7038 (89.7) |
| Ill, blackout | 98 (1.2) |
| Drowsy, sleepy, fell asleep, fatigued | 56 (0.7) |
| Physical impairment (no details) | 25 (0.3) |
| Other physical impairments | 90 (1.1) |
| | 95 (1.2) |
| Unknown if physically impaired | 536 (6.8) |
| Use of protective restraints ($n = 6551$) | |
| None | 275 (4.2) |
| Lap and shoulder belts | 5746 (88.0) |
| Lap belt | 71 (1.1) |
| Shoulder belt | 39 (0.6) |
| Unknown specifications/other | 399 (6.1) |
| Travel speed ($n = 3192$) | 20.17 (19.63)† |
| Police-reported injury severity ($n = 7847$) | |
| None | 5282 (67.3) |
| Possible injury | 968 (12.3) |
| Nonincapacitating | 722 (9.2) |
| Incapacitating | 732 (9.3) |
| Fatal injury | 126 (1.6) |
| Injured, severity unknown | 15 (0.2) |

*The values are number with percentages in parentheses, unless indicated otherwise.
†The values are mean (SD).

187 of 7541 (2.5%) running stop signs and 663 of 7541 (8.8%) hit-and-run accidents. Most of these results were supported by similar findings from previous studies on older drivers.[21–23]

## Inferential statistics

### *Person-level factors*

Age, gender, and physical impairments were significant predictors of motor vehicle injuries. Compared to drivers between 65 and 74 years of age, those belonging to the 75–84 years (odds ratio [OR] = 1.2, 95% confidence interval [CI] = 1.1–1.3) and 85 and older age groups (OR = 1.3, 95% CI = 1.1–1.6) were more likely to be injured in a crash. Female drivers were 1.5 times more likely to get injured in a crash than male drivers (95% CI = 1.3–1.6), and compared to drivers with physical impairments, those without physical impairment were 73% less likely to get injured in a crash (Table 3).

### *Environment-level factors*

Drivers who did not negotiate work or construction zones were 1.7 times more likely (95% CI = 1.1–2.6) to get injured than those who negotiated work or construction zones. Compared to intersection-related crashes, those who traveled on alleyways, ramps, or bridges were 31% less likely (95% CI = 0.57–0.82) to be injured; and compared to those who traveled on roads that were curved, drivers traveling on straight roads were 17% less likely (95% CI = 0.6–1.0) to have a crash-related injury. While weather conditions yielded no significant differences in crash-related injuries, roads without traffic control devices yielded a lesser risk of crash-related injuries, as did driving on adverse road conditions (snow/slush/dirt/oil). Month of the year showed no significance, but 2 days of the week, Monday (OR = 0.79, 95% CI = 0.64–0.98) and Friday (OR = 0.77, 95% CI = 0.62–0.95), showed a reduced risk for crash-related injuries (Table 3).

### *Vehicle-level factors*

Crashes without vehicle-contributing factors were associated with more than 2 times likelihood (95% CI = 2.05–3.48) of crash-related injuries. Drivers involved in nonimpact crashes (losing control or rollover) had a more than 2.7 times likelihood (95% CI = 1.5–4.7) of being injured than those injured in side-impact crashes. Surprisingly, these participants were about 2 times more likely (95% CI = 1.5–2.8) to be injured in a crash due to loss of vehicle control, and 16% less likely (95% CI = 0.75–0.94) to be injured as a result of other vehicle crash events (Table 3).

**Table 3.** Regression variables with presence or absence of injury as the dependent variable*

| Variable | *P* | OR | 95% CI for OR Lower | 95% CI for OR Upper | SE |
|---|---|---|---|---|---|
| *Person-level variables* | | | | | |
| Age | | | | | |
| 65–74 | | (Referent) | | | |
| 75–84 | .01† | 1.19 | 1.07 | 1.33 | 0.06 |
| 85+ | .01† | 1.32 | 1.08 | 1.62 | 0.10 |
| Gender | | | | | |
| Female | .01† | 1.46 | 1.32 | 1.62 | 0.05 |
| Driver drinking in vehicle | .62 | 0.90 | 0.58 | 1.38 | 0.22 |
| Physical impairment (none) | .01† | 0.27 | 0.20 | 0.35 | 0.14 |
| *Environment-level variables* | | | | | |
| Interstate highway (No) | .16 | 0.86 | 0.70 | 1.06 | 0.11 |
| Work zone/construction (No) | .01† | 1.69 | 1.12 | 2.56 | 0.21 |
| Junction/interchange | | | | | |
| Intersection related | | (Referent) | | | |
| Junction/interchange (No) | .35 | 1.08 | 0.92 | 1.28 | 0.09 |
| Alleyway/ramp/bridge | .01† | 0.69 | 0.57 | 0.82 | 0.09 |
| Horizontal road alignment | | | | | |
| Curve | | (Referent) | | | |
| Straight | .04† | 0.83 | 0.69 | 0.99 | 0.09 |
| Vertical road alignment | .10 | | | | |
| Sag/hillcrest | | (Referent) | | | |
| Level | .22 | 0.80 | 0.55 | 1.15 | 0.19 |
| Grade | .80 | 0.71 | 0.48 | 1.04 | 0.20 |
| Traffic control (none) | .01† | 0.83 | 0.72 | 0.96 | 0.07 |
| Road surface condition | | | | | |
| Wet | | (Referent) | | | |
| Dry | .60 | 1.06 | 0.85 | 1.33 | 0.11 |
| Snow/slush/dirt/oil | .01† | 0.46 | 0.29 | 0.72 | 0.23 |
| Weather condition | | | | | |
| Wet | | (Referent) | | | |
| None | .56 | 0.92 | 0.70 | 1.22 | 0.14 |
| Rest | .85 | 1.04 | 0.67 | 1.62 | 0.22 |
| Hour of crash | | | | | |
| 8 AM–4 PM | | (Referent) | | | |
| 5 PM–8 PM | .59 | 1.05 | 0.88 | 1.26 | 0.09 |
| 9 PM–7 AM | .54 | 0.96 | 0.83 | 1.10 | 0.07 |
| Day | | | | | |
| Sunday | | (Referent) | | | |
| Monday | .03† | 0.79 | 0.64 | 0.98 | 0.11 |
| Tuesday | .08 | 0.82 | 0.66 | 1.02 | 0.11 |
| Wednesday | .22 | 0.87 | 0.71 | 1.08 | 0.11 |
| Thursday | .06 | 0.82 | 0.66 | 1.01 | 0.11 |
| Friday | .01† | 0.77 | 0.62 | 0.95 | 0.11 |
| Saturday | .52 | 0.93 | 0.74 | 1.16 | 0.11 |
| Month | | | | | |
| January | .08 | 1.24 | 0.97 | 1.57 | 0.12 |
| February | .32 | 1.14 | 0.88 | 1.47 | 0.13 |

(*Continues*)

**Table 3.** Regression variables with presence or absence of injury as the dependent variable* (*Continued*)

| Variable | *P* | OR | 95% CI for OR Lower | Upper | SE |
|---|---|---|---|---|---|
| March | .69 | 1.05 | 0.82 | 1.34 | 0.13 |
| April | .64 | 0.94 | 0.74 | 1.21 | 0.13 |
| May | .44 | 1.10 | 0.86 | 1.41 | 0.13 |
| June | .23 | 0.86 | 0.67 | 1.10 | 0.13 |
| July | .03† | 1.30 | 1.02 | 1.66 | 0.12 |
| August | .07 | 1.25 | 0.98 | 1.59 | 0.12 |
| September | .81 | 1.03 | 0.81 | 1.32 | 0.13 |
| October | .26 | 1.14 | 0.91 | 1.44 | 0.12 |
| November | .88 | 0.98 | 0.77 | 1.25 | 0.12 |
| December | | (Referent) | | | |
| *Vehicle-level veriables* | | | | | |
| Precrash events | | | | | |
| Driver related | | (Referent) | | | |
| Other vehicle | .01† | 0.84 | 0.75 | 0.94 | 0.06 |
| Loss of vehicle control | .01† | 2.03 | 1.45 | 2.84 | 0.17 |
| Vehicle-contributing factors (none) | .01† | 2.67 | 2.05 | 3.48 | 0.13 |
| Initial point of impact | | | | | |
| Side | | (Referent) | | | |
| None | .01† | 2.70 | 1.53 | 4.74 | 0.29 |
| Front | .71 | 0.98 | 0.87 | 1.10 | 0.06 |
| Back | .10 | 0.87 | 0.74 | 1.03 | 0.08 |
| Other | .08 | 0.40 | 0.15 | 1.10 | 0.52 |

*OR indicates odds ratio; CI, confidence interval; and SE, standard error.
†Significant at $P \leq .05$.

## DISCUSSION

This population of older drivers demonstrated similar *person-level* characteristics to what are known from the older driver safety literature.[21–23] As a group, they had a greater number of male drivers, were mainly law-abiding citizens with minimal level of drinking and driving, and had excellent compliance with the use of lap or shoulder restraints. They drove cautiously as evidenced by the number of low-speed crashes; a high percentage of injury-related crashes occurred at intersections.[9] While those without physical impairments had a lesser risk of sustaining crash-related injuries, female drivers were more prone to crash-related injuries.[2,3]

The variety of *environment-level* risk and protective factors identified through this study perhaps brings a new impetus to older driver safety. In an attempt to prevent injuries and to save lives, one must consider the possible impact of enhancing environmental safety. For example, encouraging the use of alternate ways with fewer intersections or junctions is not only acceptable but also practical, and perhaps even cost-effective. The benefits of protective factors, such as driving on straight (opposing to curved) roads and negotiating roads with no traffic control devices, may be considered by city engineers and traffic planners for future planning. Driving on adverse road conditions (eg, snow/slush/dirt/oil) appears to be a protective factor, perhaps due to the possibility of older drivers employing self-restriction and therefore avoiding driving on these roads.[24] The same principle, that of self-restriction, may explain why Mondays and

Fridays, generally the more traffic-dense days of the week, were inversely associated with crash-related injuries.

*Vehicle-level* factors discerned that older drivers are, compared to injuring others, at a greater risk of injuring themselves in a crash. Considering enhancing vehicle-level factors to provide greater protection during losing control or rollover may be an important risk-reducing strategy for future injuries and fatalities.

The main study limitations must be considered in interpreting the findings.[19] Effect sizes may be inflated or deflated because of the cross-sectional nature of the study. Some factors that are inherently associated with crash-related injuries (eg, the use of mind-altering medications and underlying medical conditions), have not been taken into account. In addition, some important *person-level* variables (eg, vision) were excluded because of missing data and others (eg, race) were not recorded in the 2003 GES database. In addition, no temporality or cause and effect can be determined.

## CONCLUSION

Although many of the *person-level* factors associated with crash-related injuries are documented in the literature, this study showed that using a socioecological model elucidates the *environment-level* and *vehicle-level* factors. Although study limitations must be considered, enhancing road surface conditions and vehicles safety may be an acceptable, practical, and cost-effective risk-reducing and safety-enhancing option.

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