Traffic Injury Prevention, 10:361–367, 2009

ISSN: 1538-9588 print / 1538-957X online
DOI: 10.1080/15389580902973635

The Association of Driver Age with Traffic Injury Severity in Wisconsin

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Objectives: *To quantify the association of driver's age with the risk of being injured, dying, and experiencing injuries of different severity when involved in a motor vehicle crash.*

Methods: *Data from the Wisconsin Crash Outcome Data Evaluation System (CODES) from 2002 to 2004 were used to study 602,964 drivers of a car or truck who were involved in a motor vehicle crash. Odds ratios (OR) or relative risk ratios (RRR) and their 95 percent confidence intervals (CIs) were calculated for age groups, in relation to the outcomes of injury, fatality, and injury severity using logistic regression models, which controlled for sex, alcohol use, urban/rural location, seat belt use, ejection, airbag deployment, vehicle type, and highway class.*

Results: *Increasing age was strongly associated the risk of dying or experiencing severe injuries for drivers involved in motor vehicle crashes with the greatest risk in drivers 85 years and older. Compared to drivers aged 25–44, drivers 85 years and older had the highest risks for moderate injury (ISS = 9–15; RRR = 5.44, 95% CI: 3.97–7.47), severe injury (ISS = 16–74; (RRR = 4.32, 95% CI: 2.73–6.84), and fatality (OR = 10.93, 95% CI: 7.76–15.38). In contrast, drivers 85 years and older had no increase in risk for minor injury (ISS = 1–8; OR = 0.94, 95% CI: 0.84–1.05).*

Conclusions: *The oldest drivers involved in motor vehicle crashes had the highest risk for severe injury and fatality. In light of the increasing number of the oldest drivers and their poor outcomes from severe trauma, substantial morbidity can be expected to occur in the oldest drivers. Evidence-based measures to reduce the risks to older drivers should continue to be developed, evaluated, and implemented.*

Keywords Motor vehicle crash; Injury; Injury severity score; Older drivers

INTRODUCTION

Between the years 2000 and 2030, the population of Americans 65 years and older is expected to grow from 35 to 70.3 million (US Bureau of the Census 2000). In 2030, drivers aged 65 and older will account for up to 25 percent of all driver fatalities (Lyman et al. 2002). Older drivers have an elevated risk of involvement in a motor vehicle crash (MVC); drivers 75 years and older suffer more crash injuries per million miles driven than any other age group, except for the youngest drivers 16–19 years of age (Massie et al. 1995). In addition to being at increased risk for a crash, the elderly are also more likely to be killed when they crash (Federal Highway Administration 1997).

Received 13 October 2008; accepted 16 April 2009.
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The elevated rate of crash occurrence in older drivers has long been attributed to changes associated with aging, such as delayed reaction time and visual impairment (Kline et al. 1992; Owsley et al. 1991). Recent research, however, has questioned the role of these traditional risk factors. Hakamies-Blomqvist et al. (2002) found the higher rate of crash involvement per million miles driven for older drivers was because they drive fewer miles per year than younger drivers. This so-called low mileage bias is due to the fact that drivers who drive more miles per year have a lower crash risk per mile driven. Langford, Methorst, et al. (2006) and Alvarez and Inmaculada (2008) have supported these findings by showing that drivers of all age groups had an increased crash risk with lower annual mileage. Staplin et al. (2008), however, concluded that the exposure methods used in these studies are subjective and may be unreliable and encouraged further study in this area with an objective measure of driver exposure.

Though the cause of the higher rate of crash occurrence in older drivers is controversial, the reason that elder drivers have an increased risk of fatal crash outcomes is widely thought to be frailty (Braver and Trempel 2004; Eberhard 2008; G. Li et al. 2003; Organisation for Economic Co-operation and Development [OECD] 2001; Padmanaban 2001). The frailty of aging has been attributed to decreased bone strength, which results in increased risk for fractures (Dejeammes and Ramet 1996; Padmanaban 2001). G. Li et al. (2003) compared the effects of driver frailty and increased crash rate on driver fatality and found that frailty was the most important factor. This result was supported by Eberhard in 2008. Evans (2001) found that older drivers tended to have more fatal crash outcomes even after controlling for the severity of impact, which supports the importance of older driver frailty. Among older drivers, the risk for suffering a fatal crash has been shown to increase steadily with age (Massie et al. 1995).

The increased rate of crashes in older drivers, along with their greater risk of fatal crash outcomes, is troubling in light of the aging of the population and projections that older adults will continue driving to a later age than in the past (Federal Highway Administration 1997). The growing number of drivers over age 85 is of particular cause for concern. These drivers have the highest mileage-adjusted fatal MVC rate of any age group (Braver and Trempel 2004). In addition to the challenges of delayed reaction time and visual impairment experienced by seniors, dementia plays an important role in those over 85. The Canadian Study of Health and Aging Working Group (1994) reported that the overall prevalence of dementia among seniors 65 years and older was 8.0 percent. However, the prevalence rose sharply with increasing age from a prevalence of 2.4 percent in those 65–74 years old to 34.5 percent for seniors aged 85 and over. Drivers with dementia have an increased risk for crashes (Charlton et al. 2004; Dobbs 2005; Vaa 2003). Several studies have shown that dementia patients lack insight into their impairment and often continue to drive until they have suffered crashes (Friedland et al. 1988; Kazniak et al. 1991).

The purpose of this study was to assess injury outcomes of elderly drivers who are in motor vehicle crashes. We hypothesized that older drivers, particularly those 85 years and older, would have elevated risks for more severe nonfatal injuries, as well as fatal injuries.

METHODS

Database

The information analyzed in this study is from the Wisconsin Crash Outcome Data Evaluation System (CODES) database for the years 2002–2004. For motor vehicle crashes in Wisconsin, CODES links data from police reports provided by the Wisconsin Department of Transportation with emergency department (ED) and hospital discharge data from the Wisconsin Hospital Association and death certificates from the Wisconsin Department of Health Services. The linkage process is designed to identify and link police reports of motor vehicle crash injuries and the corresponding discharge records from ED visits and hospitalizations that occur within 15 days of the crash. The linkage casts a broad net and then uses a probabilistic algorithm to identify matching records. Initially, all ED and hospital discharges with a ICD-9 code indicative of an injury are included. Thus, both individuals with non-crash injuries and those being treated for late effects of crash injuries, after the 15-day time frame of interest, would be included. These are matched to a database of all police motor vehicle crash reports, regardless of whether an injury was noted by the reporting officer. Crashes occurring on a public roadway must be reported if there is an injury or if property damage is $1000 or more. Records from these sources are linked using CODES 2000 software, which uses a probabilistic algorithm based on E-code information and 14 other data elements such as crash location, date of event, and hospital service area to link records. Only records with a cumulative match probability of 0.99 or greater based on the algorithm were considered linked. A detailed analysis of linkage data from 2003 found that 57.9 percent of crash records with an injury noted by the police officer were matched to a ED or in-patient hospital record. On the other hand, less than 1 percent of crash records with no injury noted by the police officer were matched to an ED or in-patient hospital record. This study was approved by the Institutional Review Board at Medical College of Wisconsin.

Study Population

Wisconsin CODES from 2002–2004 contained 997,977 individuals involved in an MVC in Wisconsin for which an accident report was submitted to the Wisconsin Department of Transportation. We limited our study to drivers only and to the following vehicles: passenger cars (521,186 drivers), utility trucks (110,724 drivers), straight trucks (14,338 drivers), and truck tractors (14,296 drivers). Only drivers aged 16 or older were included. All drivers in the database for whom age was unavailable were excluded. Seven drivers with a software-assigned injury severity score (ISS) of 75 (incompatible with life) who were discharged alive from hospital were excluded. This left 602,957 drivers (58% male and 42% female) in the study. Injured drivers (61,074) included in the study were determined by hospital or ED discharge data, and deaths (1458) were a combination of those reported at the scene by a police officer and those reported by a hospital or emergency department. In cases where police report on injury occurrence disagreed with hospital records, hospital records were used. Hospital discharge data indicative of a motor vehicle injury that did not link with police data were omitted from our analyses.

Variable Definitions

Injury, death, and injury severity were the outcome variables in this study. Injury severity score (ISS; Baker et al. 1974) was estimated based on hospital or emergency department discharge diagnoses (with hospital diagnoses taking precedence) using the ICDMAP-90 program (Johns Hopkins University 2002). Crash records with no discharge record were assigned an ISS of zero. Deaths were assigned an ISS of 75. For analysis of the association of age with severity of injury, ISS scores were grouped into the following categories: ISS = 1–8 (minor injury), ISS = 9–15 (moderate injury), ISS = 16–74 (severe injury).

Driver age was categorized into seven groups: 16–19 years, 20–24 years, 25–44 years, 45–64 years, 65–74 years, 75–84 years, and 85 years and older. Other variables considered included sex, alcohol use (indicated versus not indicated), urban/rural location, seat belt use (belted, unbelted, and unknown), ejection (ejected and not ejected), airbag deployment (deployed, not deployed, and unknown), vehicle type (passenger cars, utility trucks, straight trucks, and truck tractors), and highway class (local roads, county roads, state highways, and federal interstate).

Statistical Analysis

Stata (Windows version 10.0, College Station, Texas) was used for statistical analysis. Statistical significance was defined as a two-tailed p value less than 0.05.

Three different models were used to determine the association between driver age and injury severity. Two of them utilized unconditional logistic regression to calculate odds ratios (OR): one used ISS greater than one as the outcome variable, and the other used fatal vs. nonfatal as the outcome. The first model excluded fatalities and the second model was restricted to injury to the driver by excluding those with an ISS of zero. A third model used multinomial logistic regression with ISS categorized into four levels (excluding deaths) as the outcome variable to calculate relative risk ratios (RRR). Multinomial logistic regression was used because this model violated the proportional odds assumption of ordinal logistic regression. To express the precision of the OR or RRR estimates, 95 percent confidence intervals (CI) were calculated for all models.

All models included the potentially confounding factors age, sex, alcohol use, urban/rural crash location, seat belt use, ejection, airbag deployment, vehicle type, and highway class.

RESULTS

Characteristics of drivers involved in motor vehicle crashes in Wisconsin from 2002 to 2004 are shown in Table I. The majority of drivers in crashes were male (58.0%). Most crashes occurred in urban locations (74.1%). Local roads were the most common place for a crash (52.7%), followed by state highways (32%). Alcohol use was noted in 4.6 percent of drivers and not using a seat belt was reported for 7 percent of drivers.

Table II shows the association of age and severity of injury in drivers involved in motor vehicle crashes. Over 50,000 drivers 65 years and older were involved in crashes in Wisconsin from 2002 to 2004, including 4238 drivers 85 years and over. During this period, 1458 drivers died (0.2% of all drivers in crashes), 1249 (0.2% of all drivers in crashes) had a severe injury, and 1890 (0.3% of all drivers in crashes) experienced a moderate injury as a result of their crash. Older drivers experienced substantially worse outcomes; of drivers 85 years and older in a motor vehicle crash 1.1 percent died, 0.5 percent had a severe injury, and 1.1 percent had a moderate injury.

Table I Characteristics of drivers involved in motor vehicle crashes in Wisconsin (2002–2004).

	N(%)
Drivers	602,957 (100.0)
Male	349,527 (58.0)
Injured	61,074 (10.1)
Alcohol use noted	27,512 (4.6)
Urban/rural	
Urban	446,775 (74.1)
Seat belt use	
Unbelted	42,348 (7.0)
Airbag	
Deployed	50,629 (8.4)
Not deployed	136,076 (22.6)
Ejection status	
Ejected	2,165 (0.4)
Highway class	
Local roads	317,581 (52.7)
County roads	52,755 (8.8)
State highways	192,644 (32.0)
Federal interstate	39,977 (6.6)

To assess the association of driver age and crash outcomes in more detail, we controlled for a number of potentially confounding factors in logistic regression models. In these models the risk of experiencing any nonfatal injury (ISS = 1–74) in a crash increased slightly with age; however, the difference in risk between the youngest and oldest age group was small (Table III). A much stronger trend of increasing risk with increasing age was found for fatalities. Compared with drivers 25–44 years old, the odds of being killed in a crash were especially high for older adults, ranging from threefold (aged 65–74), to over tenfold (aged 85 and over).

Among drivers who survived a crash, the severity of the injury also tended to increase with age (Table IV). Compared to drivers 25–44 years old, the odds ratio of having a moderate or severe injury increased in each age group from 45–64 years and above. In contrast, there was no appreciable association of driver age with the risk of minor injury.

DISCUSSION

This study found that older drivers experience poor injury outcomes when they are involved in a crash. This study expands on the existing literature by showing that older drivers injured in crashes experience more severe injuries even in nonfatal crashes. The risk of both moderate and severe injuries increased steadily from age 45 on. The risks of moderate and severe injury and death were particularly elevated in the oldest age group, 85 years and above.

It is well known that elderly drivers have an increased risk for fatality when they are involved in a crash (G. Li et al. 2003; McGwin and Brown 1999). They also have an increased risk of death per vehicle mile traveled (Evans 2000; G. Li et al. 2003; Lyman et al. 2002; Stutts and Martel 1992). Cook et al. (2000) demonstrated that these older drivers have an increased mortality rate at both the crash scene and during subsequent

Table II Severity of injury by driver age.

	Severity of injury (ISS Score)											
	None ISS = 0		Minor ISS = 1–8		Moderate ISS = 9–15		Severe ISS = 16–74		Dead ISS = 75		Total	
Age	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
16–19	84,626	89.3	9,450	10.0	268	0.3	220	0.2	188	0.2	94,752	100.0
20–24	79,026	89.1	8,983	10.1	291	0.3	171	0.2	235	0.3	88,706	100.0
25–44	204,974	89.9	21,618	9.5	626	0.3	414	0.2	448	0.2	228,080	100.0
45–64	128,000	90.8	11,938	8.5	407	0.3	273	0.2	331	0.2	140,949	100.0
65–74	24,869	90.3	2,369	8.6	128	0.5	74	0.3	86	0.3	27,526	100.0
75–84	16,664	89.1	1,717	9.2	125	0.7	77	0.4	123	0.7	18,706	100.0
85+	3,724	87.9	402	9.5	45	1.1	20	0.5	47	1.1	4,238	100.0
Total	541,883	89.9	56,477	9.4	1,890	0.3	1,249	0.2	1,458	0.2	602,957	100.0

hospitalization. Our results show an increased risk for fatality in elder drivers, especially those aged 85 and over, which is consistent with these past studies.

This study found that older drivers sustain more severe injuries even in nonfatal crashes. Drivers 85 years and older were at a particularly high risk, being over five times more likely to suffer a moderate or severe injury than drivers aged 25–44. Coupled with our results and previous work that drivers 85+ are more likely than any other age group to die or to suffer any injury in a crash, it appears that these drivers experience the worst crash outcomes across the entire spectrum of crashes, with the most appreciable increase in risk being in crashes that result in more severe injury. A study by Newgard (2008) used multivariate regression models to show that age was a strong predictor of serious injury in motor vehicle crashes, a finding that supports our results. The mechanism for the increased risk of injury among older drivers appears to be the fragility, or diminished physiologic reserve, that accompanies old age (Braver and Trempel 2004; Eberhard 2008; G. Li et al. 2003; OECD 2001; Padmanaban 2001).

Previous research indicates that drivers 85 years and older have the highest rate of passenger vehicle fatal crash involvement per mile (Braver and Trempel 2004; Stamatiadis and Deacon 1995). In this study of drivers involved in a crash, this group was ten times more likely to die than drivers aged 25–44, even after controlling for key factors such as alcohol use, type of road, vehicle type, and seat belt use. The literature indicates that these drivers 85 and older are more likely to cause fatality to themselves and their passengers (who tend to also be older adults) than to occupants of other vehicles. However, Braver and Trempel also found that older drivers posed an increased risk of injury and property damage to other road users.

Table III Odds ratios for injury and fatality by driver age.[a]

	Injured[b]		Killed[c]	
Age	OR	95% CI	OR	95% CI
16–19	0.86	0.84–0.88	0.97[d]	0.80–1.17
20–24	0.88	0.85–0.90	0.94[d]	0.79–1.12
25–44	1.00	Reference	1.00	Reference
45–64	1.00[d]	0.97–1.02	1.90	1.61–2.23
65–74	1.00[d]	0.95–1.04	3.03	2.35–3.92
75–84	1.00[d]	0.95–1.05	6.46	5.13–8.14
85 and over	1.06[d]	0.96–1.18	10.55	7.48–14.86

[a]Controlled for sex, alcohol use, urban/rural location, seat belt use, ejection, airbag deployment, vehicle type, and highway class.
[b]Excludes fatalities.
[c]Excludes crashes in which the driver was not injured.
[d]Not statistically significant, $p > 0.05$. All other $p < 0.05$.

Table IV Relative risk ratios for injury severity by age.[a]

Minor Age	RRR	95% CI
16–19	0.86	0.84–0.88
20–24	0.88	0.86–0.91
25–44	1.00	Reference
45–64	0.98	0.96–1.00
65–74	0.95	0.91–0.99
75–84	0.93	0.88–0.98
85 and over[b]	0.94	0.84–1.05
Moderate Age		
16–19	0.82	0.70–0.95
20–24	0.79	0.68–0.92
25–44	1.00	Reference
45–64	1.40	1.23–1.60
65–74	2.37	1.94–2.90
75–84	3.34	2.72–4.10
85 and over	5.44	3.97–7.47
Severe Age		
16–19[b]	1.02	0.85–1.22
20–24	0.67	0.55–0.81
25–44	1.00	Reference
45–64	1.53	1.30–1.80
65–74	2.38	1.83–3.08
75–84	3.37	2.58–4.39
85 and over	4.32	2.73–6.84

[a]Multinomial logistic regression was used to calculate relative risk ratios compared to uninjured drivers controlling for sex, alcohol use, urban/rural location, seat belt use, ejection, airbag deployment, vehicle type, and highway class. The outcome variable was a grouping of injury severity scores: ISS = 0 (no injury), ISS = 1–8 (minor injury), ISS = 9–15 (moderate injury), ISS = 16–74 (severe injury). Deaths were excluded.
[b]Not statistically significant, $p > 0.05$.

Our finding that there was only a slight, nonsignificant increase in risk for nonfatal injury in the oldest drivers (85+) was surprising. This result is at odds with previous literature, which demonstrates that elderly drivers are at increased risk for injury due to frailty (Kent et al. 2003; Padmanaban 2001; Viano et al. 1990). The weak association of age with the risk of any injury in this study was due to the preponderance of minor injuries and the lack of any increased risk of minor injury with increased age.

Before exploring the implications of this study, it is worth considering its limitations, particularly those of the CODES database, which is based on linkage of crash reporting forms and hospital discharge data. Crash reporting forms are limited by what police record for certain fields. For example, alcohol use as a contributing factor tends to be underreported. Because seat belt usage is frequently self-reported by the driver after the crash, it is likely that it is over reported. Seat belt use tends to increase with age (L. Li et al. 1999) and the effect of overreporting is likely to be greatest in young drivers. Crash report forms do not record the change in velocity that occurs during a crash. Change in velocity has a large impact on injury severity (Baker et al. 1974). Hospital discharge data have their own limitations (Hunt et al. 1999) and do not contain the detailed clinical information available in trauma registries. Finally, the linkage between crash reporting forms and hospital discharge data was based on a probabilistic match and was incomplete.

The population aged 85 and over is the fastest growing segment of the elderly (Day 1996). In light of their increased risk of motor vehicle crash injury, some states have implemented special provisions for elderly driver's license renewals, such as requiring drivers to renew their licenses more frequently, renew in person, or take a vision test (Insurance Institute for Highway Safety, Highway Loss Data Institute 2008). Among these special provisions, only in-person renewal has been shown to decrease fatality rates in elderly drivers (Grabowski et al. 2004). Most other age-triggered assessments have been shown to be ineffective (Decina and Staplin 1993; Lange and McKnight, 1996; Langford, Fitzharris, Koppel, et al. 2004; Langford, Fitzharris, Newstead, et al. 2004; Levy et al. 1995). A recent study in Florida showed that mandatory visual acuity testing prior to license renewal decreased the MVC fatality rate in drivers over age 80 by 17 percent (McGwin et al. 2008). This policy did not reduce the number of MVCs in the elderly, however, and the authors concluded that the mechanism by which visual acuity testing reduced MVC fatality is unclear and further research into this area is needed (McGwin et al. 2008).

Some promising alternative approaches to age-triggered assessments for the identification of unsafe older drivers are being developed. For example, a three-tiered assessment system for all drivers who are renewing their licenses has been developed by the California Department of Motor Vehicles in Association with the National Highway Traffic Safety Administration (NHTSA). The first two tiers assess driver's visual, mental, and physical abilities; knowledge; and perceptual response time. Drivers who do poorly in the first two tiers must undergo a road test (tier 3). Further study is needed to determine the usefulness of this method (Hennessy and Jahnke 2005). Another approach is a community referral system such as the one proposed in the Australasian model license reassessment (Fildes et al. 2008). This model would rely on members of the community such as physicians and police officers to refer unsafe drivers (of all ages) for further screening. Valid off-road screening tests would be necessary for this system to work. Promising possibilities are currently being studied (Charlton et al. 2003; Fildes et al. 2004). This type of approach is advantageous in that it does not discriminate against drivers based on age, making it more likely to gain acceptance.

The impact of driving cessation on the elderly must be taken into consideration. Losing the ability to drive may limit the freedom and independence of seniors. Forced cessation of driving may lead to social isolation and depression in the elderly, which is why physicians, state licensing agencies, and others should work together to help the elderly drive safely for as long as possible (Fonda et al. 2001; Marottoli et al. 1997). For example, certain deficiencies can be overcome with vehicle modifications such as larger mirrors and reduced effort steering systems. There are therapists, called driver rehabilitation specialists, who can prescribe these. Physicians and state licensing agencies can refer the elderly to these specialists if it is appropriate (Wang et al. 2003). State licensing agencies can also give restricted licenses as opposed to revoking the license altogether.

CONCLUSION

Our findings show that the older drivers involved in motor vehicle crashes are more likely to die or have more severe injuries than other age groups. These adverse outcomes are most pronounced for drivers over age 85. In light of the increasing number of the oldest drivers and their poor outcomes from severe trauma, substantial morbidity can be expected to occur in the oldest drivers. Evidence-based measures to reduce the risks to older drivers should continue to be developed, evaluated, and implemented. Two approaches appear particularly promising. Mandatory in-person license renewal has been shown to decrease fatality in elderly drivers (Grabowski et al. 2004). Non-age-based methods for identifying unsafe drivers, such as the Australasian model license reassessment, have also shown promise and may avoid the issue of age discrimination (Fildes et al. 2008).

ACKNOWLEDGEMENTS

This work was supported, in part, by Centers for Disease Control and Prevention (CDC) Grant R49 CE001175 and National Institute on Aging (NIA) Training Grant 1T35AG029793–01. The authors thank Richard Miller, Wayne Bigelow, and Martha Florey for linking the CODES data and providing access to them.

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