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Trends in Older Driver Crash Involvement Rates and Fragility: An Update

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Abstract

Objective: Previous research has shown that fatal crash involvement rates per licensed driver aged 70 and older declined significantly more per year than rates for middle-aged drivers aged 35-54 during 1997-2008, and per vehicle mile traveled from 1995-96 to 2001-02. Analyses of police-reported crash data during 1997-2005 indicated that the greater declines for older drivers were due to decreases in crash involvement and in the risk of dying in the crashes that occurred. The current study examined if trends in crash rates, crash involvements, and survivability persisted into more recent years.

Methods: Trends for drivers 70 and older were compared with trends for drivers aged 35-54 for national fatal passenger vehicle crash involvements per 100,000 licensed drivers during 1997-2012 and for national fatal passenger vehicle crash involvements per vehicle miles traveled in 1995-96, 2001-02, and 2008. Using police-reported crash data during 1997-2008 from 20 states, trends in involvement rates in non-fatal crashes of various severities per 100,000 licensed drivers and changes in the odds of death and the odds of death or serious injury in a crash were compared between older and middle-aged drivers.

Results: During 2007-2012, declines in national fatal crash involvement rates per licensed driver were similar for drivers 70 and older and middle-aged drivers (18 percent each). However, when considering the entire study period, fatal crash involvement rates continued to reflect a substantially larger decline for drivers 70 and older than for middle-aged drivers (42 vs. 30 percent per licensed driver during 1997-2012, 39 vs. 26 percent per vehicle mile traveled from 1995-06 to 2008). When analyses of police-reported crash data were extended through 2008, non-fatal injury crash involvement rates per licensed driver declined more for older than for middle-aged drivers (39 vs. 30 percent), and unlike in prior research, average annual declines were significantly larger for drivers 80 and older. Property damage-only crash involvement rates similarly declined significantly more for older than for middle-aged drivers (15 vs. 3 percent). Drivers 70 and older in 1997 were 3.5 times more likely than middle-aged drivers to die in a crash, and this ratio declined to 3.2 by 2008.

Conclusions: Although declines in fatal crash involvement rates in recent years have not differed between older and middle-aged drivers, this did not undo earlier gains for older drivers. The recent slowing in the relative magnitude of the decline for older drivers may be related to the differential effect of the U.S. recession on fatal crash involvements of drivers in these age groups. The decreased

likelihood of being involved in a crash of any severity and increased survivability when a crash occurred held when examining data through 2008, and for drivers 80 and older, significant declines in crash involvement relative to middle-aged drivers extended to non-fatal injury crashes.

Keywords: Older drivers; Crash trends

Research Topics: Older drivers

1. Introduction

According to the U.S. Census Bureau (2012, 2013), the population aged 70 and older is expected to increase from 29 million in 2012 to 64 million in 2050. The population aged 80 and older is expected to nearly triple, from 12 million to 31 million. Adults 70 and older comprised 9 percent of the population in 2012, and by 2050 this figure is projected to increase to 16 percent. With the increase in the older population comes an increase in older drivers. A larger percentage of the population 70 and older are remaining licensed, and data from national household travel surveys suggest that they are driving more miles (Federal Highway Administration (FHWA) 2009, 2014). Anticipated increases in the number of older licensed drivers, and in the miles they drive, have led to concern regarding their potential effects on the number of older drivers involved in crashes and the resulting increases in fatalities and injuries (e.g., Lyman et al., 2002).

Older drivers have lower police-reported crash involvement rates per capita than younger drivers, largely because older drivers travel fewer miles annually than drivers in most other age groups. However, fatal and police-reported crash involvement rates per mile traveled begin to increase at age 70 and are markedly higher than those of middle-aged drivers by age 80. Multiple factors can increase an older driver's crash risk. Age-related declines in cognitive, visual, and physical function can increase the likelihood that an older driver will be involved in a crash (Anstey et al., 2005; Owsley et al., 1998; Sims et al., 2001; Stutts et al., 1998). The fragility of crash-involved occupants, that is, the chance that they sustain serious injuries when involved in a crash, also increase with age (Kahane, 2013; Li et al., 2003). Kahane (2013) estimated that the fatality risk for a driver aged 21-96 rises by about 3 percent for each year of aging if exposed to a similar physical insult in a crash.

Given the large increases in the number of older licensed drivers, and their heightened fragility and risk of crashing, it would be expected that fatal crash involvements among older drivers would have increased in recent years. However, Cheung and McCartt (2011) reported that passenger vehicle fatal crash involvements among drivers 70 and older decreased during 1997-2008, as did fatal crash involvement rates per licensed driver during the same period and non-fatal crash involvement rates per licensed driver during 1997-2005. Moreover, fatal crash involvement rates decreased significantly more for drivers 70 and older than for middle-aged drivers aged 35-54, with the strongest declines seen among

drivers 80 and older. Declines in rates of involvement in non-fatal crashes of all severities were generally larger for drivers 75 and older relative to middle-aged drivers, although differences only approached or reached significance for property damage-only crashes. Analyses additionally showed that the odds of a crash-involved driver sustaining a fatal injury declined significantly during 1997-2005 for drivers 70 and older relative to middle-aged drivers. Thus, the reduced fatality rate appeared to reflect both a decline in crash involvements, and a decline in frailty among older drivers.

Cheung and McCartt (2011) used the number of licensed drivers as an exposure measure, and this measure has limitations. For instance, counts of licensed drivers do not account for reductions in annual mileage seen for older drivers, and may include some drivers who are deceased or no longer drive. Vehicle miles traveled is another useful measure of driving exposure. Cheung et al. (2008) found that fatal crash involvement rates per mile traveled for drivers 70 and older also decreased significantly relative to drivers aged 35-54 from 1995-06 to 2001-02. Because more recent travel data were not available, Cheung and McCartt (2011) were not able to examine if declining trends in fatal crash involvement rates per mile traveled continued past 2001-02.

The goal of the current study is to update Cheung and McCartt (2011) with the most recent data, including data from the 2008-09 National Household Travel Survey. As in Cheung and McCartt (2011), when data were available, trend analyses began in 1997, the year that older driver fatal crash involvements peaked in the United States.

2. Methods

Trends in annual rates of involvements in fatal and police-reported crashes of different severities per licensed driver were examined for older drivers and compared with trends in rates for middle-aged drivers. In addition, trends in the rates of involvements in fatal and police-reported crashes per vehicle miles traveled were examined for older drivers relative to middle-aged drivers, based on the three most recent national household travel surveys. Analyses also examined trends in the risk that a crash-involved older driver would sustain a fatal injury in a crash of any severity, relative to the trends in the risk for a middle-aged driver.

Only passenger vehicle (i.e., car, van, SUV, and pickup) driver crash involvements and miles driven in passenger vehicles were included. Older drivers were defined as those aged 70 and older, and

were further examined by age groups of 70-74, 75-79, and 80 and older. Middle-aged drivers were defined as ages 35-54. These drivers were selected as a comparison group because they generally are without age-related impairments that affect older drivers, and they are less likely to engage in the risk-taking (e.g., alcohol-impaired driving, speeding) that boosts crash involvement rates for younger drivers.

2.1. Data sources

Driver license data during 1997-2012 were obtained from yearly counts by state and age provided by FHWA (2014) based on data submitted by the states. Annual national population estimates by age were obtained from the U.S. Census Bureau and were used to describe the older population during the study period.

Data on vehicle miles traveled were obtained from national household travel surveys conducted periodically by FHWA. The current study used data from the Nationwide Personal Transportation Survey conducted during 1995-96 and the National Household Travel Surveys conducted during 2001-02 and 2008-09 (FHWA, 2009). These surveys collected information on travel from a nationally representative sample of U.S. households, weighted to provide national estimates for a year of travel. Information is collected for all members of the household so that travel can be estimated by mode (e.g., passenger vehicle, bicycle, or public transportation), age, gender, time of day, vehicle type, and other factors. The surveys produced estimates of travel during April 1995-March 1996, April 2001-March 2002, and January 2008-December 2008, and these estimates were used to calculate crash rates during these same periods. For simplicity, the surveys and their associated crash rates are referred to as the 1995, 2001, and 2008 surveys and rates.

Data on fatal crashes were obtained from the National Highway Traffic Safety Administration's (NHTSA) Fatality Analysis Reporting System (FARS). FARS is a census of fatal motor vehicle crashes occurring on public roads in the United States in which a death to a vehicle occupant or other road user occurs within 30 days.

Data on police-reported crashes of all severities were obtained from two sources. NHTSA's National Automotive Sampling System General Estimates System (NASS GES) is a nationally representative probability sample of police-reported crashes that can be weighted to produce annual national estimates. Weighted GES data were used to calculate rates of involvement in police-reported

crashes of all severities combined per mile traveled during the three household survey periods. Imputed data were used when available in GES files to account for missing data.

Vehicle type in FARS and GES was based either on decoding the vehicle identification number (VIN), or the FARS body type variable or imputed GES body type variable if the VIN was unavailable. In the state crash databases, it was based on the body type variable.

GES samples were not large enough to examine annual trends in crashes of different severities by age, and thus trends in involvements in crashes of different severities were examined using data from state crash databases. Crash records from 19 states (California, Connecticut, Florida, Georgia, Kansas, Kentucky, Maryland, Michigan, Minnesota, Missouri, Montana, New Mexico, New York, North Carolina, Pennsylvania, Ohio, South Carolina, Virginia, and Wisconsin) were obtained from NHTSA's State Data System (SDS), which consists of electronic crash data files from participating states converted into a common format. Additional electronic crash data for Oregon were obtained from the Crash Analysis and Reporting Unit of the Oregon Department of Transportation. These 20 states provide relatively wide geographic coverage of the United States.

The latest year for which data were available for a large number of states was 2008. State crash data were extracted for 1997-2008. States were eligible for inclusion if data were available for most years of the study period, including 1997 and 2008, and there was information on driver age and injury severity that closely resembled the KABCO scale. The KABCO scale is used by police officers at crash scenes to classify crashes into one of five severity categories based on the most serious injury involved: K, killed; A, disabling/incapacitating injury; B, evident/non-incapacitating injury; C, possible injury/complaint of pain; and O, no apparent injury. These definitions may vary slightly for different law enforcement agencies. Counts of fatal crashes in state data may vary from counts in FARS due to different inclusion criteria and definitions of variables. New York, Pennsylvania, and Minnesota were each missing 1 year of crash data (2001, 2002, and 2003, respectively), and Pennsylvania's data for 2004 was incomplete and therefore excluded. Rates of involvements in crashes of different severities per licensed driver by age were examined. The rates of crash involvements per mile traveled could not be examined because the national household surveys do not contain large enough state-level samples of drivers by age.

2.2. Analyses

Analyses were conducted with all drivers in the respective age groups, and separately for male and female drivers. Analysis of covariance (ANCOVA) was used to examine linear trends in annual passenger vehicle crash involvement rates per 100,000 licensed drivers for drivers aged 70-74, 75-79, and 80 and older relative to the comparison group of drivers aged 35-54. Trends in fatal crash involvement rates were examined per licensed driver during the years 1997-2012, and trends in rates of involvements in police-reported crashes of different severities per licensed driver were analyzed during the years 1997-2008. Parameter estimates from the ANCOVA models are reported as estimates of annual changes in crash rates for each age group, and of differences between groups (e.g., changes for each older driver group relative to middle-aged drivers). Crash involvement rates varied by state. Fatal crash involvement rates for drivers 70 and older, for instance, ranged from 11.2 to 37.2 in different states for the years of the study period combined. To control for state variation in the models using state crash data, state was added as a categorical variable.

State crash data also were used to compute the odds that a crash-involved driver would sustain a fatal injury in a crash of any severity for each year during 1997-2008. Annual changes in the risk that a crash-involved older driver would die relative to a middle-aged crash-involved driver were then examined with logistic regression. The same approach was used to examine the odds that an older crash-involved driver would sustain a fatal or serious injury relative to a middle-aged driver.

The four missing state-years of data were excluded from ANCOVA and logistic regression analyses, but these data were interpolated in the figures and tables displaying trends of state crash data. The percentage change in rates from the prior year to the missing year by age group in the states with data were used to estimate the missing values. For example, in the 19 states with data for 2000 and 2001, the serious injury crash involvement rate for drivers aged 70-74 decreased 1.7 percent. New York's serious injury crash involvement rate for drivers 70-74 in 2000 was 87.1 per 100,000 licensed drivers, and a rate of 85.6 was estimated for the missing year of 2001. There were 441,659 licensed drivers aged 70-74 in New York in 2001, and so an estimated 378 serious injury crash involvements were derived.

Because vehicle miles traveled data were only available for 3 years (1995, 2001, 2008), a different method was used to analyze changes in fatal crash involvement rates per 100 million miles traveled for older drivers relative to middle-aged drivers. For each of the 3 years, fatal crash involvement

rate ratios (RRs) were calculated for the older driver groups relative to the middle-aged driver group; RRs were defined as the ratio of the fatal crash involvement rate for each older age group to the rate for the middle-aged group. Ratios of the RR for 2008 to the RR for 1995 were then computed. For instance, the ratio for drivers aged 70-74 was computed using equation (1), where DIR is driver fatal crash involvements per 100 million vehicle miles traveled.

$$RR_ratio_{70-74} = \frac{DIR_2008_{70-74} / DIR_2008_{35-54}}{DIR_1995_{70-74} / DIR_1995_{35-54}} \quad (1)$$

Confidence intervals and RR ratios were derived using methods similar to those used by Cheung et al. (2008), Shope et al. (2001), and Ulmer et al. (2000). RR ratios of less than 1 indicated that the fatal crash involvement rate for the older driver group decreased from 1995 to 2008 relative to the fatal crash involvement rate for middle-aged drivers.

3. Results

3.1. Trends in crash involvement rates per licensed driver

3.1.1. National trends in fatal crash involvement rates

Passenger vehicle fatal crash involvements of drivers 70 and older generally trended upward from 1975, peaking at 4,823 in 1997, and then declined 25 percent to 3,616 in 2012. Fatal crash involvements of passenger vehicle drivers declined during 1997-2012 by 24 percent for drivers aged 70-74, 38 percent for drivers aged 75-79, and 15 percent for drivers 80 and older.

Table 1 summarizes the trends in population and fatal crashes for people 70 and older from 1997 to 2012 and trends in licensure from 1997 to 2012. Decreases in fatal crash involvements occurred despite substantial increases in the older population and older licensed drivers during this period. From 1997 to 2012, the population and the number of licensed drivers aged 70 and older increased by 19 and 30 percent, respectively, and the percentage of older drivers who were licensed increased from 73 to 79 percent. Licensure rates from 1997 to 2012 also increased more with age, from 86 to 89 percent for ages 70-74, from 77 to 84 percent for ages 75-79, and from 55 to 68 percent for ages 80 and older (not in table).

Figure 1 shows fatal crash involvements of passenger vehicle drivers per 100,000 licensed drivers for ages 35-54, 70-74, 75-79, and 80 and older during 1997-2012. Rates declined by 30 percent for middle-aged drivers, compared with progressively larger declines of 36 percent for drivers 70-74, 46 percent for drivers 75-79, and 49 percent for drivers 80 and older; among drivers 70 and older combined, the fatal crash involvement rate declined by 42 percent. The rates for middle-age drivers and drivers 70-74 were similar throughout the study period and lower than the rates for drivers aged 75-79 and 80 and older. At the beginning of the study period, drivers 80 and older had by far the highest fatal crash rate, nearly twice the rate of drivers aged 35-54 and 70-74. By 2012, the fatal crash involvement rate for drivers 80 and older was 1.4 times the rate for drivers 35-54 and 70-74.

Table 2 summarizes the results of the ANCOVA model that examined linear trends in the annual fatal crash involvement rates per 100,000 licensed drivers by age. During 1997-2012, there were significant declines in fatal crash involvement rates for drivers in each age group. Average annual declines were larger with increasing age, and fatal crash involvement rates for drivers aged 75-79, 80 and older, and 70 and older combined declined by significantly more per year than rates for drivers aged 35-54. The difference in average annual declines between drivers 70-74 and middle-aged drivers was marginally significant ($p < 0.07$).

It is evident in Figure 1 that declines in fatal crash involvement among middle-aged drivers accelerated during 2007-10, whereas declines among some older driver age groups began to slow after 2008. From 2007 to 2012, fatal crash involvement rates declined by 18 percent each among middle-aged drivers and among drivers 70 and older. Average annual declines during 2007-12 were examined with another ANCOVA model (Table 2). Declines in fatal crash involvement rates were similar for middle-aged drivers and drivers aged 70-74 and 80 and older. For drivers 75-79 average annual declines were larger than for middle-aged drivers, but not significantly so.

3.1.2. Trends in rates of crashes of all severities in 20 study states

Analyses of crashes of all severities per licensed driver focused on trends in 20 study states during 1997-2008. The states comprised a reasonable sample of older drivers in the United States during the study years. Fifty-eight percent of all licensed drivers 70 and older in the United States were licensed in the study states. People aged 70 and older were 9 percent of the population of the study states and

the U.S. population during this time. The licensure rate among adults aged 70 and older was 74 percent in the study states and 75 percent in the United States.

Trends in crash involvement rates per 100,000 licensed drivers were examined for fatal, non-fatal injury (A-, B-, and C-level), and property damage-only (O-level) crashes. Non-fatal injury crashes were further divided into serious (A-level) and moderate and minor injury combined (B- and C-level) crashes. Involvement rates in non-fatal crashes were much higher for middle-aged drivers than for the older drivers (Figure 2). Serious injury crash involvement rates among the older driver age groups differed markedly in 1997, with involvement rates increasing with age, but differences dissipated by 2008. There were only small differences in moderate/minor and property damage-only crash involvement rates among the older driver age groups throughout the study period. Similar to national fatal crash involvement rates, decreases in involvement rates in crashes of various severities in the 20 states declined by larger percentages as driver age increased. For instance, from 1997 to 2008 involvement rates in non-fatal injury crashes declined by 30 percent for drivers 35-54, 36 percent for drivers 70-74, 38 percent for drivers 75-79, 45 percent for drivers 80 and older, and 39 percent for drivers 70 and older combined; involvement rates in property damage-only crashes declined by 3 percent for drivers 35-54, 9 percent for drivers 70-74, 12 percent for drivers 75-79, 24 percent for drivers 80 and older, and 15 percent for drivers 70 and older combined.

Table 3 describes the results of ANCOVA models that examined linear trends in involvement rates in crashes of different severities for older drivers relative to middle-aged drivers, controlling for state variation. Trends in fatal crash involvement rates were similar to national trends. Fatal crash involvement rates declined for each age group, and declines were stronger for older drivers than for middle-aged drivers; these differences were significant for drivers aged 75-79, 80 and older, and 70 and older combined. The same patterns were seen for involvement rates in crashes of all severities combined. Rates of non-fatal injury crash involvements also declined significantly at each age. Declines were larger for drivers 75 and older than for middle-aged drivers, and were significantly so for drivers 80 and older; results were the same when serious and moderate/minor injury crashes were examined separately. Annual declines in property damage-only crash involvement rates were significant for older drivers, and marginally significant for middle-aged drivers. The declines were larger for the older driver age groups

than for the middle-aged drivers, and differences were significant for drivers 75-79, 80 and older, and 70 and older combined.

3.2. National trends in crash rates per vehicle miles traveled

3.2.1. Trends in driving exposure

Older adults drove considerably fewer miles per year, on average, than middle-aged adults during 1995, 2001, and 2008, and drove fewer miles with increasing age (Table 4). However, older drivers increased their annual mileage by larger percentages than middle-aged drivers from 1995 to 2008. Average annual mileage decreased for middle-aged drivers and two of the three older driver groups from 2001 to 2008, but declines were larger among the middle-aged drivers than among these older drivers.

Adults 70 and older drove a larger percentage of their miles in cars than middle-aged drivers, and a smaller proportion in vans, SUVs, and pickup trucks, than middle-aged drivers during each survey period. The percentage of miles driven in cars decreased across the survey periods for drivers in all age groups; however, the shift was not uniform across the older age groups. In 1995, 53 percent of miles driven by ages 35-54 and 82-85 percent of miles driven by ages 70-74, 75-79, and 80 and older were in cars. In 2008, the percentage of miles driven in cars for drivers aged 35-54, 70-74, 75-79, and 80 and older was 49 percent, 57 percent, 63 percent, and 77 percent, respectively.

3.2.2. Trends in crash involvement rates per mile traveled

Figure 3 depicts fatal crash involvement rates per 100 million miles traveled during 1995, 2001, and 2008 by all age groups. Fatal crash involvement rates per mile traveled were the highest for the youngest and oldest drivers. In 2008, for example, drivers aged 16-19 and 80 and older had 5 fatal crashes per 100 million miles traveled, compared with 1 fatal crash per 100 million miles traveled for drivers aged 35-54. Figure 3 also shows that drivers 75 and older experienced dramatic decreases in fatal crash involvement rates in each survey period. Only drivers aged 16-19 experienced a drop comparable with that of drivers 75 and older from 2001 to 2008. Similar patterns were seen in the rates of police-reported crashes per mile traveled (Figure 4). Both the youngest and oldest drivers had higher police-reported crash involvement rates than middle-aged drivers, but rates were highest among the youngest drivers. Rates declined among drivers aged 75-59 and 80 and older in each survey period.

Fatal crash involvement rates per 100 million miles traveled for drivers aged 35-54, 70-74, 75-79, and 80 and older were examined in more detail in Table 5. The fatal crash rate ratio relative to middle-aged drivers declined between 1995 and 2001 and then increased between 2001 and 2008 for drivers 70-74, declined steadily for drivers 75-79, and declined sharply for drivers 80 and older between 1995 and 2001 and declined more modestly between 2001 and 2008. Between 1995 and 2008, the declines for drivers in each older age group relative to middle-aged drivers were significantly larger. Fatal crash involvement rates relative to middle-aged drivers declined by 8 percent for drivers 70-74 (RR ratio = 0.92, 95% CI = 0.85-1.00), 30 percent for drivers 75-79 (RR ratio = 0.70, 95% CI = 0.63-0.78), and 39 percent for drivers 80 and older (RR ratio = 0.61, 95% CI = 0.57-0.66).

Trends in RR ratios of police-reported crashes of all severities combined per mile traveled followed similar trends (table not shown). Declines in RR ratios were larger for fatal than for police-reported crashes.

3.3. Trends in the odds of dying in a crash

For the 20 study states, changes during 1997-2008 in the odds that a crash-involved passenger vehicle driver would sustain a fatal injury were examined for all older drivers aged 70 and older and 80 and older relative to middle-aged drivers. In 1997, it was 3.5 times more likely that a driver aged 70 and older would die in a crash relative to a driver aged 35-54, and 5.4 times more likely that a driver 80 and older would die relative to a middle-aged driver (Table 6). The odds of dying in a crash generally declined gradually for older drivers during the study period and were variable for middle-aged drivers before declining after 2005. By 2008, the odds ratios for drivers 70 and older and 80 and older relative to middle-aged drivers were 3.2 and 4.3, respectively.

Logistic regression was performed to estimate average annual changes in the odds of dying in a crash for each age group, controlling for state variation (Table 7). Model coefficients are exponentiated rather than expressed as log odds. Differences in the average annual changes in odds between groups are expressed as odds ratios. Drivers 70 and older and drivers 80 and older experienced significant declines in the odds of dying in a crash, and reductions were significantly larger than the marginally significant decline experienced by middle-aged drivers.

The same analyses were used to examine changes over time in the odds of a crash-involved driver sustaining a serious or fatal injury. Drivers 70 and older were about 1.5 times more likely to sustain a fatal or serious injury in a crash than middle-aged drivers throughout the study period, and drivers 80 and older were 1.9 times more likely to sustain a fatal or serious injury than middle-aged drivers in 1997, and 1.8 times more likely in 2008 (Table 8). Odds declined significantly for all age groups, and the average annual decrease in odds was significantly larger for drivers 80 and older than for middle-aged drivers (Table 9).

Coding manuals for some of the 20 states indicated that reporting thresholds for property damage-only crashes changed during the study period. The same set of analyses were performed using only crashes that resulted in an injury of any severity, which are the crash types that would be less likely to be subject to reporting variations. Trends in the odds of sustaining a fatal injury, and serious or fatal injury, were similar when property damage-only crashes were excluded from analyses.

4. Discussion

The present study extends Cheung and McCartt (2011) with the most recent data to examine how the fatal crash involvement rate for drivers 70 and older has changed since peaking in the mid-1990s. During recent years fatal crash involvement rates declined by similar magnitudes for middle-aged and older drivers, but this has not reversed the overall trend. Accounting for the entire study period that began when the fatal crash involvement rates for older drivers were at their highest, the national fatal crash involvement rate for drivers 70 and older has declined to a significantly larger extent than for middle-aged drivers 35-54. Declines have been largest among drivers 80 and older. These findings hold when using two measures of driving exposure, the number of licensed drivers and vehicle miles traveled. Data from 20 states indicate that crash involvement rates per licensed driver for drivers 70 and older also declined in non-fatal crashes. For drivers 70 and older, declines in property damage-only crash involvement rates were significantly larger than for middle-aged drivers. Cheung and McCartt (2011) did not find significant differences in declines in non-fatal injury crash involvement rates for any older driver age group relative to middle-aged drivers, but in this sample that included more states and more years of data, declines in non-fatal injury crash involvement rates were significantly larger for drivers 80 and older than for middle-aged drivers.

Age-related fragility increases the likelihood that an older crash-involved driver will sustain a fatal or serious injury (Kahane, 2013; Li et al., 2003). During 1997-2008, the odds that a crash-involved driver 70 and older sustained a fatal injury declined, significantly more so than for middle-aged drivers. In this same period, the odds that a crash-involved driver sustained a serious or fatal injury also declined significantly more for drivers 80 and older than for middle-aged drivers. The decline in fatal crash rates among older drivers appear to reflect both a decrease in crash involvement, as evidenced by declining rates of involvement in crashes of each severity, and increased survivability in crashes that do occur.

There are a number of possible factors that may have contributed to an increase in crash survivability among older drivers. Hung et al. (2011) examined results from the 1998, 2004, and 2008 waves of the Health and Retirement Study, a nationally representative survey of older adults in the United States, and found that the proportion of adults 75-79 and 85 and older reporting disabilities affecting instrumental activities of daily living declined during this period. If the older population has become healthier, it may help explain why crash-involved older drivers are more likely to survive. Better health may also be related to the increase in licensure rates and associated with a lower prevalence of cognitive and visual impairments, the latter of which could affect the likelihood of crash involvement. Improved emergency medical services or trauma care may have also increased the likelihood that a crash-involved older driver would survive.

Research has shown that improvements in vehicle design, including improved crashworthiness and availability of safety features, have reduced fatality rates per registered vehicle year (Farmer, 2005; Farmer & Lund, 2006; Teoh & Lund, 2011). It is possible that some vehicle improvements may have benefitted older drivers more than middle-aged drivers, and evidence suggests that this has been the case with occupant protection technologies. Kahane (2013) estimated the effectiveness of various occupant protection technologies in preventing fatalities for drivers and right front-seat passengers aged 13-49 and 70-96. Seat belts in cars model years 1996 and earlier were generally less effective for occupants 70-96 than for those aged 13-49. However, technologies that became prevalent in new vehicles beginning in the late 1990s and early 2000s, including frontal airbags and seat belts equipped with pretensioners and load limiters, were generally equally as effective for older and younger occupants.

Side airbags with head and torso protection in cars were more effective for older than for younger occupants.

Although seat belts that were less effective for older occupants began to be replaced by technologies that were equally as effective for younger and older occupants in new vehicles near the beginning of the study period, it takes time for new technologies to proliferate through the vehicle fleet. For example, starting in 1996 federal law required driver frontal airbags in some vehicles and in 1997 more than 90 percent of new vehicle models offered standard or optional driver frontal airbags, yet in 1997 only about a third of registered vehicle models offered standard or optional driver frontal airbags (Highway Loss Data Institute (HLDI), 2012). Driver frontal airbags were standard or optional equipment in 88 percent of registered vehicle models by 2010. Insurance data indicates that drivers 70 and older tend to drive vehicles from earlier model years than middle-aged drivers (HLDI, 2013a), which suggests that these features may have taken somewhat longer to appear in older drivers' vehicles than in those of middle-aged drivers.

It is important to note that although some safety features may be more or less beneficial for older than for younger occupants, there is no evidence that any recently implemented vehicle design improvements benefit only occupants in some age ranges but not others. For instance, although side airbags with head and torso protection are estimated to reduce fatalities in nearside impacts by 45 percent for front-seat occupants aged 70 and older, which is significantly larger than the 30 percent reduction estimated for front-seat occupants aged 13-49, they are effective at reducing fatalities among occupants of all ages (Kahane, 2013). NHTSA proposed adding a "silver car" rating to their New Car Assessment Program to help older drivers choose vehicles that would potentially be safer for them (Office of the Federal Register, 2013), but it is unclear if it is possible to identify vehicle features that would benefit older drivers without also being beneficial to younger drivers. To investigate if there are discrepancies in the vehicle models that are safest for older and younger drivers, the Insurance Institute for Highway Safety (IIHS, 2013a) calculated standardized death rates per vehicle registration by vehicle make and model for model years 2006-08 vehicles during calendar years 2006-09, adjusted for various factors that affect fatal crash risk, for a hypothetical elderly population 65 and older and a hypothetical

non-elderly population. The rank order of vehicles by driver death rates were highly correlated for the two populations, which suggests that the safest vehicles apply to younger and older drivers alike.

The changing size of the vehicles driven by older drivers may have also influenced crash survivability. Drivers 70 and older travel most often in cars, but during the study period became more likely to travel in SUVs, vans, and pickup trucks. The larger size and weight of SUVs, vans, and pickup trucks provide occupants more protection in two-vehicle crashes than that provided by cars, although incompatibility between cars and larger vehicles has narrowed in recent years with changes in vehicle design (O'Neill & Kryrchenko, 2004; Teoh & Nolan, 2012). Occupant protection in two-vehicle crashes is especially relevant to older drivers given that a larger percentage of their fatal crash involvements are in multiple-vehicle crashes compared with those among younger drivers. In 2012, multiple-vehicle crashes accounted for 67 percent of fatal crash involvements among drivers 70 and older, compared with 60 percent of fatal crash involvements among drivers 35-54 (IIHS, 2013b). Drivers 70 and older are overrepresented in crashes at intersections (Mayhew et al., 2006), where side impact crashes are likely to occur. Passenger vehicle incompatibility has typically been most pronounced in front-to-side impacts (O'Neill & Kryrchenko, 2004).

There are similarly a number of factors that could have contributed to the decrease in crash involvements among older drivers. Changes in travel patterns among older drivers may influence crash risk. Older drivers drive fewer miles annually than drivers in other age groups, but the average annual mileage for drivers 70 and older increased by a larger percentage than for middle-aged drivers from 1995 to 2001, and then decreased by a smaller percentage from 2001 to 2008. This is especially the case for drivers 75 and older, who increased their average annual mileage by more than 50 percent from 1995 to 2008. Langford et al. (2006) demonstrated that among drivers of all ages, those who drive a very small number of miles per year have the highest crash risk per mile traveled. The elevated crash rate among low-mileage drivers has been hypothesized possibly to be related to differences in where higher and lower mileage drivers drive, and self-regulation among lower-mileage drivers. For instance, lower-mileage drivers tend to be more likely to use local roads with more intersections and possible conflict points. Older adults who drive fewer miles may also do so because they are self-regulating their driving in response to impairments, which would suggest an elevated crash risk when they do drive. The large

increase in average annual mileage among older drivers from 1995 to 2008 may mean that the proportion of older drivers who are low-mileage drivers decreased during the study period, which could reflect changes in the types of roads frequented by drivers and in underlying impairments related to crash risk.

In recent years the larger declines in older driver fatal crash involvement rates relative to middle-aged drivers have slowed. During 2007-12, fatal crash involvements per licensed driver declined for drivers 70 and older, but average annual declines were somewhat smaller than during the entire study period; for middle-aged drivers, average annual declines were larger. A possible factor may be the U.S. recession during this period. It is well-established that traffic fatalities drop during recessions and rise when the economy is strong (Evans & Graham, 1988; Ruhm, 1995). Some factors hypothesized to influence the decrease in fatal crashes in a poor economy include declines in commuting to work, alcohol-impaired driving, and speeding (Cotti & Tefft, 2011; Evans & Graham, 1988; Ruhm, 1995), which are types of driving that are less frequent among drivers 70 and older.

There is evidence that the association between traffic fatalities and the economy weakens with the increasing age of the vehicle occupant (Evans & Graham, 1988), and research has found that driver age plays a role in the effect of the unemployment rate on crashes and driving exposure. Cotti and Tefft (2011) modeled the relationship between traffic fatalities and economic indices during 2003-09 and found that increases in the unemployment rate were associated with lower traffic fatality rates per capita among ages 30-59, but not among those 60 and older. An examination of the number of insured teenage and middle-aged drivers during 2006-12 by HLDI (2013b) indicates that fluctuations in the number of insured drivers in an age group is related to changes in the unemployment rate of people in that age group. The unemployment rates of the population aged 35-54 increased from a low of 2.9-3.2 in the second quarter of 2007 to a high of 8.5-9.4 in the first quarter of 2010, whereas the unemployment rate among the population 70 and older increased less during this time, from 3.1-3.5 in the second quarter of 2007 to 5.7-6.8 in the first quarter of 2010 (Bureau of Labor Statistics, 2013). If the relationship between the unemployment rate and the number of insured drivers holds for older drivers, it could be the case that driving exposure decreased to a larger degree among middle-aged drivers than among older drivers during the recession.

Data from the household travel surveys are consistent with this idea. The 2008 household travel survey was conducted at the beginning of the U.S. recession, and average annual mileage from 2001 to 2008 declined by a larger percentage among middle-aged drivers than among older drivers. However, because most middle-aged people have a driver's license, the licensing data used as the exposure measure to examine declines in fatal crash involvement rates during 2007-12 may not be as sensitive to reductions in driving among that group. During the past decade, less than 20 percent of the population aged 70-74 and less than 10 percent aged 75 and older have remained in the workforce (Bureau of Labor Statistics, 2013), which further suggests that unemployment would have a smaller effect on this group than on the middle-aged population. It remains to be seen how trends will persist as the economy recovers.

To examine if travel patterns differed by driver, vehicle, and environmental characteristics, analyses using vehicle miles traveled as the exposure measure were conducted separately by driver gender and time of day (day vs. night). Analyses using licensed drivers as the exposure measure were conducted separately by driver gender. Although the magnitude and statistical significance of declines relative to middle-aged drivers sometimes differed from combined effects, patterns were similar to those reported for all drivers combined and were not reported.

Some limitations of this study should be noted. The FHWA license counts that were used as an exposure measure in some analyses may include some drivers who no longer drive or who are deceased, especially in states with longer renewal periods. Motorcycle endorsements and commercial licenses may also be included in these counts, which could lead to overestimating the number of passenger vehicle drivers. Estimates of vehicle miles traveled by age from the household travel surveys for the older age groups are based on fewer respondents than for the middle-aged group, and may be less reliable. Given the different shortcomings of licensing counts and vehicle miles traveled data, it is encouraging that results were consistent when using both measures of exposure.

It was also a limitation that trends in police-reported crashes by severity and driver age were analyzed for 20 states rather than nationally, and that data for a large number of states were unavailable beyond 2008. Crash involvement rates varied among these states, and it is possible that the trends in these 20 states do not apply to all states. Practices in reporting crashes may change over time within a

state. The coding manuals for some states indicated that there were changes during the study period in the criteria for reporting property damage-only crashes. Trends in fatal crash involvements changed in recent years, and the same could be the case with non-fatal crashes of various severities. Analyses of trends in crash survivability did not account for the type of crash. Crash survivability was treated as a proxy for frailty, but changes in the types and severity of the crashes in which older and middle-aged drivers were involved could also have affected survivability.

The findings of this study demonstrate that older drivers experienced larger reductions in crash involvement rates than middle-aged drivers, but this result is not consistent with insurance data. HLDI (2009) examined rates of insurance collision claims per 1,000 insured vehicle years during 1997-2006, and found that claim rates for rated drivers 70 and older declined by a similar percentage as for rated middle-aged drivers. Results were comparable when the analysis was extended through 2012 (HLDI, 2013c). There were differences between the HLDI data and police-reported crash data used in the current study. The HLDI analyses include only 1-4-year-old model vehicles for each calendar year. The national household travel surveys and national crash databases collect data on the model years of all vehicles involved in travel and crashes. Analyses using vehicle miles traveled as the exposure measure were repeated restricting the data to 1-4-year-old model vehicles to examine if older drivers of newer passenger vehicles are experiencing the same reduction in crash risk. The results were similar to those of analyses including vehicles of all ages. Collision claims include many low-speed, property damage-only crashes that may not be police reported, and thus the insurance findings bring into question if the findings of this study extend to these types of crashes.

Acknowledgements

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Table 1 National counts of licensed drivers, population, and passenger vehicle driver fatal crash involvements for people 70 and older, 1997–2012.

Year	Older licensed drivers (in thousands)	Older people (in thousands)	Percent of older people who were licensed	Older driver passenger vehicle fatal crash involvements
1997	17,727	24,409	73	4,823
1998	17,911	24,794	72	4,808
1999	18,466	25,093	74	4,806
2000	18,940	25,560	74	4,574
2001	19,137	25,797	74	4,649
2002	19,877	26,005	76	4,543
2003	19,827	26,201	76	4,644
2004	19,966	26,338	76	4,355
2005	20,120	26,659	75	4,237
2006	20,589	26,885	77	4,064
2007	20,968	27,136	77	4,004
2008	21,567	27,521	78	3,739
2009	21,847	27,786	79	3,565
2010	22,264	27,833	80	3,630
2011	22,592	28,520	79	3,552
2012	23,117	29,168	79	3,616
Percent change 2012 vs. 1997	30	19	8	-25

Table 2 Change in annual passenger vehicle driver fatal crash involvement rates per 100,000 licensed drivers by driver age group, 1997-2012 and 2007-2012: summary of ANCOVA models

Driver age group and period	Annual change in fatal crash involvement rate	Difference in annual change in fatal crash involvement rate relative to change for drivers ages 35-54
1997-2012		
35-54	-0.46*	—
70-74	-0.60*	-0.14**
75-79	-0.83*	-0.37*
80+	-1.32*	-0.86*
70+	-0.84*	-0.39*
2007-2012		
35-54	-0.62*	—
70-74	-0.53*	0.09
75-79	-0.86*	-0.24
80+	-0.53*	0.09
70+	-0.63*	-0.01

* $p < 0.05$

** $p < 0.10$

Table 3 Change in passenger vehicle driver crash involvement rates per 100,000 licensed drivers by crash severity and driver age in 20 study states controlling for state variation, 1997-2008: summary of ANCOVA models

Crash severity/ driver age group	Annual change in crash involvement rate	Difference in annual change in crash involvement rate relative to change for drivers aged 35-54
Fatal		
35-54	-0.36*	—
70-74	-0.60*	-0.23
75-79	-0.94*	-0.58*
80+	-1.89*	-1.53*
70+	-0.99*	-0.63*
Serious		
35-54	-7.49*	—
70-74	-6.83*	0.66
75-79	-8.11*	-0.62
80+	-9.84*	-2.35*
70+	-7.94*	-0.44
Moderate or minor injury		
35-54	-39.35*	—
70-74	-34.27*	5.08
75-79	-40.08*	-0.73
80+	-46.18*	-6.83*
70+	-39.42*	0.07
All non-fatal injury		
35-54	-46.84*	—
70-74	-41.11*	5.74
75-79	-48.20*	-1.35
80+	-56.02*	-9.18*
70+	-47.28*	-0.37
Property damage only		
35-54	-11.45**	—
70-74	-26.79*	-15.34
75-79	-35.02*	-23.57*
80+	-52.38*	-40.93*
70+	-36.42*	-25.00*
All crashes		
35-54	-58.66*	—
70-74	-68.49*	-9.84
75-79	-84.16*	-25.50*
80+	-110.30*	-51.64*
70+	-84.69*	-25.00*

* $p < 0.05$

** $p < 0.10$

Table 4 Estimated average annual passenger vehicle miles traveled by driver age, 1995, 2001, 2008

Driver age group	Miles			Percent change 2008 vs. 1995
	1995	2001	2008	
35-54	12,673	16,983	15,379	21
70-74	6,848	10,375	9,512	39
75-79	5,571	8,786	8,936	60
80+	4,285	6,805	6,487	51
70+	5,948	9,000	8,446	42

Table 5 Fatal crash involvement rates per 100 million vehicle miles traveled (VMT) by age, 1995, 2001, 2008

Driver age group	Fatal crash involvement rate per 100 million VMT			Rate ratio (RR) relative to drivers ages 35-54			Percent change in fatal crash involvement rate, 2008 vs. 1995	Ratio of RR for 2008 to RR for 1995 (95% CI)
	1995	2001	2008	1995	2001	2008		
35-54	1.59	1.52	1.17	—	—	—	-26	—
70-74	3.11	2.45	2.11	1.96	1.62	1.80	-32	0.92 (0.85-1.00)
75-79	5.24	4.19	2.69	3.30	2.77	2.30	-49	0.70 (0.64-0.76)
80+	12.09	8.24	5.48	7.62	5.44	4.69	-55	0.61 (0.57-0.66)
70+	5.00	4.06	3.06	3.16	2.68	2.62	-39	0.83 (0.79-0.87)

Table 6 Odds that older crash-involved driver sustains fatal injury relative to driver ages 35-54, 1997-2008

	Ages 35-54		Ages 70+				Ages 80+			
	Deaths per 1,000 crashes	Odds	Deaths per 1,000 crashes	Odds	Odds ratio	95% CI	Deaths per 1,000 crashes	Odds	Odds ratio	95% CI
1997	1.84	0.0018	6.40	0.0064	3.50	(3.31, 3.70)	9.78	0.0099	5.37	(4.97, 5.80)
1998	1.86	0.0019	6.19	0.0062	3.34	(3.16, 3.53)	9.61	0.0097	5.20	(4.82, 5.61)
1999	1.78	0.0018	5.93	0.0060	3.34	(3.16, 3.54)	9.01	0.0091	5.10	(4.72, 5.50)
2000	1.80	0.0018	5.77	0.0058	3.22	(3.04, 3.40)	8.47	0.0085	4.73	(4.38, 5.12)
2001 ^a	1.84	0.0018	5.66	0.0057	3.08	(2.91, 3.26)	8.23	0.0083	4.50	(4.16, 4.86)
2002 ^a	1.94	0.0019	5.56	0.0056	2.87	(2.71, 3.04)	8.44	0.0085	4.37	(4.05, 4.71)
2003 ^a	1.87	0.0019	6.02	0.0061	3.24	(3.06, 3.42)	8.88	0.0090	4.79	(4.44, 5.16)
2004 ^a	1.87	0.0019	5.46	0.0055	2.93	(2.76, 3.11)	7.85	0.0079	4.22	(3.90, 4.58)
2005	1.95	0.0020	5.79	0.0058	2.98	(2.81, 3.16)	8.38	0.0085	4.33	(4.00, 4.68)
2006	1.89	0.0019	5.72	0.0057	3.03	(2.86, 3.22)	8.24	0.0083	4.38	(4.05, 4.74)
2007	1.79	0.0018	5.34	0.0054	2.99	(2.81, 3.18)	7.22	0.0073	4.06	(3.73, 4.41)
2008	1.64	0.0016	5.25	0.0053	3.21	(3.01, 3.42)	7.01	0.0071	4.29	(3.93, 4.68)

^aCounts of driver injuries were estimated for NY in 2001, PA in 2002 and 2004, and MN in 2003

Table 7 Results of logistic regression model of annual change in odds of crash-involved driver sustaining fatal injury in 20 study states controlling for state variation, 1997-2008.

	Annual change in odds	95% CI
35-54	0.9975**	(0.9947, 1.0003)
70+	0.9881*	(0.9842, 0.9921)
Odds ratio, 70+ vs. 35-54	0.9906*	(0.9857, 0.9955)
80+	0.9786*	(0.9727, 0.9846)
Odds ratio, 80+ vs. 35-54	0.9811*	(0.9745, 0.9876)

* $p < 0.05$

** $p < 0.10$

Table 8 Odds that older crash-involved driver sustains fatal or serious injury relative to driver ages 35-54, 1997-2008

	Ages 35-54		Ages 70+				Ages 80+			
	Deaths or injuries per 1,000 crashes	Odds	Deaths or injuries per 1,000 crashes	Odds	Odds ratio	95% CI	Deaths or injuries per 1,000 crashes	Odds	Odds ratio	95% CI
1997	20.42	0.0209	30.58	0.0316	1.51	(1.48, 1.55)	37.36	0.0388	1.86	(1.79, 1.93)
1998	19.48	0.0199	29.55	0.0305	1.53	(1.50, 1.57)	35.85	0.0372	1.87	(1.80, 1.94)
1999	18.46	0.0188	28.89	0.0298	1.58	(1.55, 1.62)	35.15	0.0364	1.94	(1.87, 2.01)
2000	17.71	0.0180	27.32	0.0281	1.56	(1.52, 1.60)	33.28	0.0344	1.91	(1.84, 1.98)
2001 ^a	17.48	0.0178	26.07	0.0268	1.50	(1.47, 1.54)	31.48	0.0325	1.83	(1.76, 1.90)
2002 ^a	17.94	0.0183	26.06	0.0268	1.46	(1.43, 1.50)	31.32	0.0323	1.77	(1.70, 1.84)
2003 ^a	17.16	0.0175	25.92	0.0266	1.52	(1.49, 1.56)	31.49	0.0325	1.86	(1.79, 1.93)
2004 ^a	16.94	0.0172	25.25	0.0259	1.50	(1.47, 1.54)	29.72	0.0306	1.78	(1.71, 1.85)
2005	16.87	0.0172	25.14	0.0258	1.50	(1.47, 1.54)	30.43	0.0314	1.83	(1.76, 1.90)
2006	15.99	0.0162	23.56	0.0241	1.49	(1.45, 1.53)	28.05	0.0289	1.78	(1.70, 1.85)
2007	15.38	0.0156	22.58	0.0231	1.48	(1.44, 1.52)	26.11	0.0268	1.72	(1.65, 1.79)
2008	14.15	0.0144	22.06	0.0226	1.57	(1.53, 1.62)	25.77	0.0264	1.84	(1.77, 1.92)

^a Counts of driver injuries were estimated for NY in 2001, PA in 2002 and 2004, and MN in 2003

Table 9 Results of logistic regression model of annual change in odds of crash-involved driver sustaining fatal or serious injury in 20 study states controlling for state variation, 1997-2008.

	Annual change in odds	95% CI
35-54	0.9712*	(0.9703, 0.9721)
70+	0.9708*	(0.9689, 0.9726)
Odds ratio, 70+ vs. 35-54	0.9996	(0.9974, 1.0017)
80+	0.9678*	(0.9648, 0.9709)
Odds ratio, 80+ vs. 35-54	0.9966*	(0.9933, 0.9999)

* $p < 0.05$

Figure 1 National fatal passenger vehicle driver crash involvements per 100,000 licensed drivers by age group, 1997-2012.

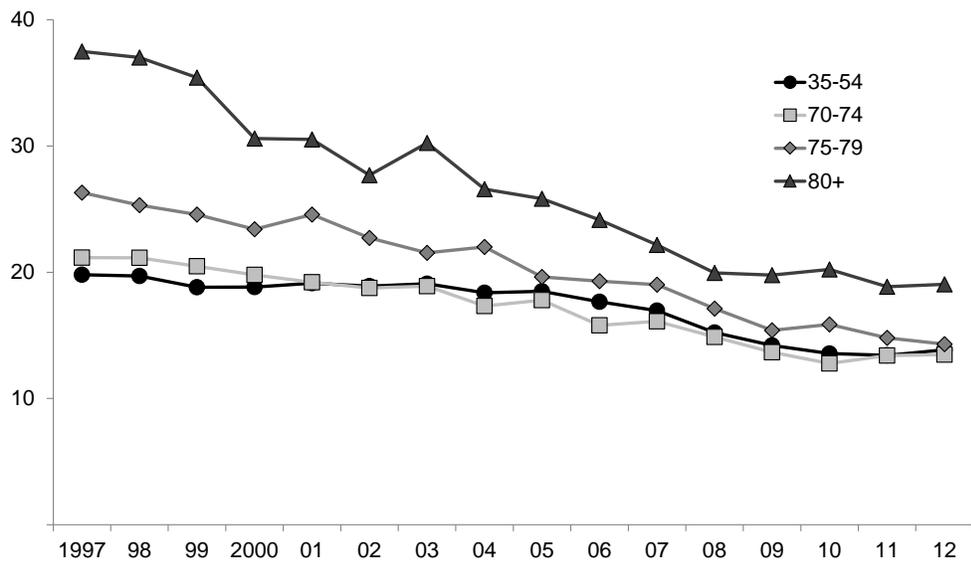
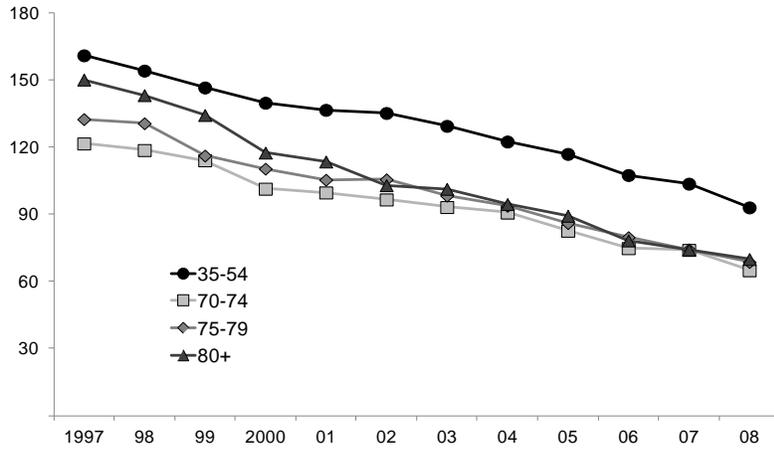
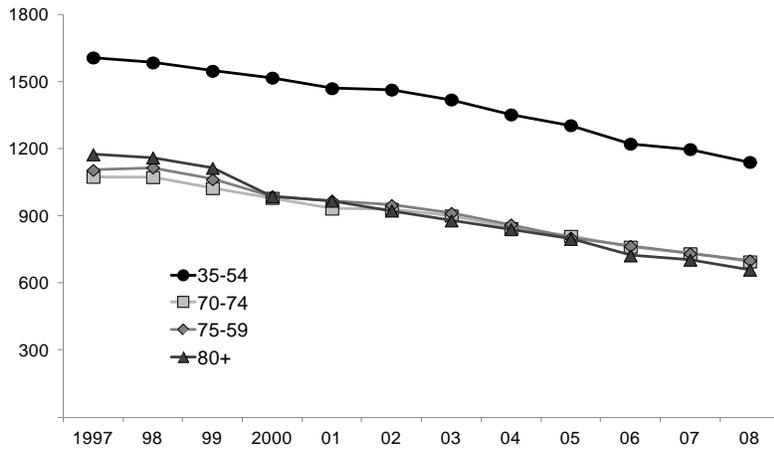


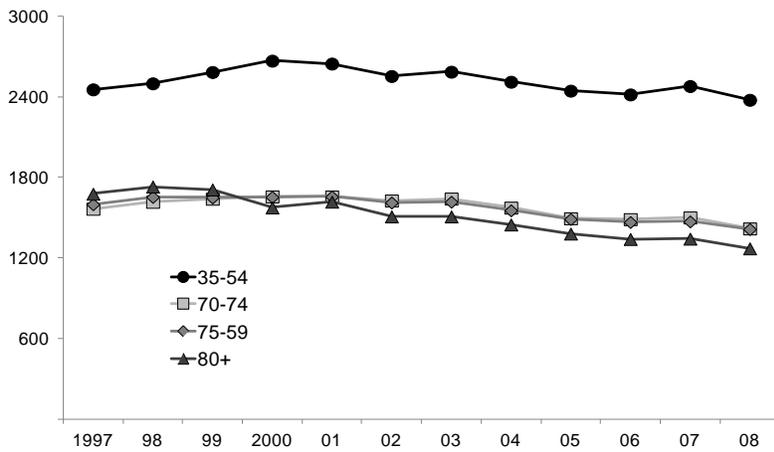
Figure 2 Trends in passenger vehicle driver crash involvements per 100,000 licensed drivers for serious injury crashes, moderate and minor injury crashes, and property-damage-only crashes in 20 study states combined^a, by driver age group, 1997-2008.



Serious injury crash involvements



Moderate or minor injury crash involvements



Property damage-only crash involvements

^a Counts of crash involvements were estimated for NY in 2001, PA in 2002 and 2004, and MN in 2003

Figure 3 National fatal passenger vehicle driver crash involvements per 100 million vehicle miles traveled by age group, 1995, 2001, 2008.

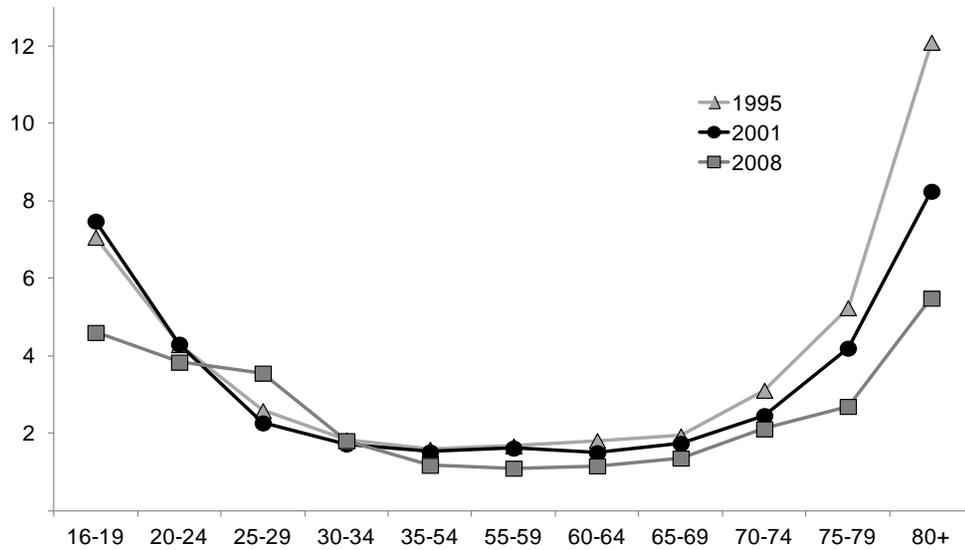


Figure 4 National police-reported passenger vehicle driver crash involvements per million vehicle miles traveled by age group, 1995, 2001, 2008.

