



Tracking progress in teenage driver crash risk in the United States since the advent of graduated driver licensing programs

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ABSTRACT

Introduction: This study examined U.S. teenagers' crash rates since 1996, when the first graduated driver licensing (GDL) program in the United State was implemented. **Methods:** Passenger vehicle driver crash involvement rates for 16–19 and 30–59 (middle-aged) year-olds were examined, using data from the Fatality Analysis Reporting System, National Automotive Sampling System General Estimates System, Census Bureau, and National Household Travel Surveys. **Results:** Per capita fatal and police-reported crash rates in 2012 were lower for 16 year-olds than for middle-aged drivers but older teenagers' rates were higher. Mileage-based fatal and police-reported crash rates in 2008 were higher for teenagers than for middle-aged drivers and higher for 16–17 year-olds than for older teenagers. In 1996–2012, teenagers' per capita fatal and police-reported crash rates declined sharply, especially for 16–17 year-olds, and more so than for middle-aged drivers. Substantial declines also occurred in teenagers' mileage-based fatal and police-reported crash rates from 1995–96 to 2008, generally more so than for middle-aged drivers. Regarding factors in fatal crashes in 1996 and 2012, proportions of young teenagers' crashes occurring at night and with multiple teenage passengers declined, more so than among older teenagers and middle-aged drivers. The proportion of fatally injured drivers who had been drinking declined for teenagers but changed little for middle-aged drivers. Improvements were not apparent in rates of driver errors or speeding among teenage drivers in fatal crashes. **Conclusions:** Teenage drivers' crash risk dropped during the period of implementation of GDL laws, especially fatal crash types targeted by GDL. However, teenagers' crash risk remains high, and important crash factors remain unaddressed by GDL. **Practical applications:** Although this study was not designed to examine the role of GDL, the results are consistent with the increased presence of such laws. More gains are achievable if states strengthen their laws.

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1. Introduction

In the United States, teenagers drive less than all but the oldest people, but their youthfulness and driving inexperience result in disproportionately high crash rates. The rates of fatal crashes and police-reported crashes per mile driven for 16–19 year-olds are about 3 times the rates for drivers 20 and older ((Insurance Institute for Highway Safety [IIHS], 2014a). In 2010, motor vehicle crashes were the leading cause of death among 13–19-year-old males and females in the United States (National Center for Injury Prevention and Control, 2012).

Several important factors contribute to teenagers' elevated crash rates. Their crash risk is particularly high during the first months of unsupervised driving, when their inexperience is most acute (Masten & Foss, 2010; Mayhew, Simpson, & Pak, 2003; McCartt, Shabanova, & Leaf, 2003). Fatal crash risk is higher at night for drivers of all ages, but especially for young drivers ((Insurance Institute for Highway Safety

[IIHS], 2014a). Transporting teenage passengers heightens a teenage driver's risk of involvement in a fatal (Preusser, Ferguson, & Williams, 1998; Tefft, Williams, & Grabowski, 2013) or non-fatal (Doherty, Andrey, & MacGregor, 1998; Williams & Ferguson, 2002) crash. Compared with having no passengers, the risk of 16–17-year-old driver deaths per mile traveled increases incrementally with one, two, and three or more passengers younger than 21 and no older passengers (Tefft et al., 2013). In contrast, the presence of at least one adult passenger has a protective effect. Speeding also is an important risk factor for crash frequency and severity. In 2012, almost one-third of teenage drivers involved in fatal crashes were judged by police to have been speeding ((Insurance Institute for Highway Safety [IIHS], 2014b). Forty-four percent of teenage drivers in fatal crashes in 2012 had other driver errors (e.g., following too closely) coded by the police. A study of novice teenage drivers in Connecticut involved in nonfatal crashes found that three factors contributed about equally to their crashes: failing to detect another vehicle or traffic control device, speeding, and losing control (Braitman, Kirley, McCartt, & Chaudhary, 2008).

In the United States, teenagers are less likely than adults to drive after drinking alcohol. However, at the same blood alcohol concentration (BAC), drivers ages 16–20 are far more likely than older drivers to

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get into a fatal or non-fatal crash (Peck, Gebers, Voas, & Romano, 2008; Voas, Torres, Romano, & Lacey, 2012). This is thought to result from the relative inexperience of young drivers with drinking, with driving, and with combining the two (Mayhew, Donelson, Beirness, & Simpson, 1986). Reductions in alcohol-related crashes of teenage drivers have been associated with minimum legal drinking age laws of 21 and “zero tolerance” laws that prohibit people younger than age 21 from driving with any alcohol in their system (Shults et al., 2001). Although all U.S. states and the District of Columbia have these laws, 15% of fatally injured drivers ages 16–17 and 30% of fatally injured drivers ages 18–19 had BACs of 0.08% or higher in 2012 ((Insurance Institute for Highway Safety [IIHS], 2014b).

Graduated driver licensing (GDL) laws have proven effective in lowering teenagers' crash risk. GDL phases in driving privileges as beginners mature and gain skills by strengthening the learner phase and adding an intermediate license before full licensure that restricts unsupervised driving in situations known to be risky. Beginning with Florida in 1996, all states and the District of Columbia have adopted some form of GDL, although the strength of GDL systems varies widely.

A large body of research has shown GDL to be effective in reducing teenagers' crash rates. In jurisdictions that adopted elements of GDL, overall crash rates among young teenagers fell 20% to 40% (Shope & Molnar, 2007), and nighttime and teenage passenger restrictions have proved effective in reducing relevant crashes (Williams, 2007). National studies found that stronger GDL laws were associated with lower per capita rates of fatal crashes or fatalities among young teenagers (Chen, Baker, & Li, 2006; Dee, Grabowski, & Morrissey, 2005; Masten, Foss, & Marshall, 2011; McCartt, Teoh, Fields, Braitman, & Hellinga, 2010; Morrissey, Grabowski, Dee, & Campbell, 2006; Trempe, 2009; Vanlaar et al., 2009).

National studies have identified the relative effectiveness of specific GDL components. In a pair of national studies by IIHS and the Highway Loss Data Institute (HLDI), significant reductions in the rates of fatal crashes and/or insurance collision claims among young teenagers were associated with the relative strength of the following licensing components: minimum learner's permit and intermediate license ages, number of required driving practice hours, and night and passenger restrictions during the intermediate license phase (McCartt et al., 2010; Trempe, 2009). Similarly, Masten, Foss, and Marshall (2013) found that lower fatal crash rates among young teenagers were associated with stronger passenger and nighttime restrictions and a minimum intermediate license age of 16 1/2 to 17. They also found that lower fatal crash rates were associated with a learner's permit holding period of 9–12 months.

As evidence of GDL's effectiveness became available, states rapidly enacted graduated licensing systems, and many strengthened their initial laws. As shown in Table 1, the result is a virtual transformation of teenage driver licensing laws in the United States since 1995.

Recent attention has focused on the effects of GDL on older teenagers' crash rates. One national study (Masten et al., 2011) reported significant increases in per capita fatal crash rates for 18 year-olds associated with strong GDL programs. However, other research found that stronger GDL programs did not significantly affect the fatal crash

rates for older teenagers (McCartt et al., 2010) and were associated with lower collision claim rates (Trempe, 2009).

Part of the debate about the effects of GDL on older teenagers has centered on the possibility that teenagers may be delaying licensure to avoid being subject to GDL restrictions. In most states, only people younger than 18 must go through GDL when they apply for a license. There is evidence that licensure rates among young teenagers may have declined in the past few years (Highway Loss Data Institute, 2013; Shults & Williams, 2013). A study that examined declining trends in the number of insured teenage drivers (ages 14–19) relative to insured adult drivers (ages 35–54) in 2006–12 found that the key factors were the economic recession and extremely high levels of teenage unemployment (Highway Loss Data Institute, 2013). Graduated driver licensing laws were shown not to have had a large impact on the level of insured 14–19 year-olds. These findings are consistent with those of national surveys of teenagers, showing that economic costs and other practical considerations, not avoidance of GDL, are the main reasons reported for delaying licensure (Tefft, Williams, & Grabowski, 2014; Williams, 2011).

Ferguson, Teoh, and McCartt (2007) examined data on teenagers' fatal and nonfatal crashes in the United States in 1996 and 2005, reporting substantial progress in reducing fatal and nonfatal crashes per population among 16-year-old drivers and large but generally smaller declines among older teenagers. Since 2005, many states had implemented or strengthened graduated licensing laws as of the time the current study was conducted. Half of the states implemented passenger restrictions (12 states) or strengthened (13 states) existing restrictions. Six states implemented nighttime driving restrictions, 9 states strengthened restrictions, and 2 states weakened them. Thirty states strengthened learner's permit requirements by implementing (3 states) or lengthening (11 states) minimum holding periods or implementing (9 states) or strengthening (15 states) supervised driving requirements. Two states raised the minimum age for obtaining a learner's permit and 1 state lowered it, and 6 states raised the minimum age for obtaining an intermediate license. All but 3 states have implemented or strengthened laws prohibiting teenage drivers from using their phones or texting specifically.

The current study updates Ferguson et al. (2007) by conducting a comprehensive examination of crash data from 1996 to 2012, the most recent year for which national crash data were available when the study was conducted. The paper presents an overview of current teenage passenger vehicle driver crash rates in the United States and changes in these rates since 1996, when the first U.S. graduated driver licensing law took effect. Important characteristics of fatal crashes also are examined.

2. Methods

The rates of involvements of teenage drivers ages 16–19 in crashes involving at least one fatality and in police-reported crashes of all severities were examined during the years 1996–2012. Crash involvements of drivers of other ages also were examined; some comparisons focus in particular on drivers ages 30–59. The crash experience of drivers ages 30–59 controls for general influences on crash rates such as economic trends. All analyses focus on passenger vehicle drivers.

Data on fatal crashes were obtained from the Fatality Analysis Reporting System (FARS), a census of motor vehicle crashes occurring on public roads in the United States and resulting in at least one death within 30 days of the crash. Data on police-reported crashes were obtained from the National Automotive Sampling System General Estimates System (NASS GES). NASS GES contains information for a nationally representative sample of police-reported crashes that can be weighted to provide national estimates. Fatal crash involvements and police-reported crash involvements were examined by driver gender and age. Fatal crash involvements for teenagers and middle-aged drivers also were examined by passenger presence, nighttime

Table 1
Teenage licensing requirements in U.S. states and District of Columbia, 1995 and January 2014.

GDL component	Number of states plus District of Columbia	
	1995	January 2014
Minimum learner's permit age 16 or older	8	8 and DC
Learner's permit for at least 6 months	0	46 and DC
30 h or more of certified practice driving	0	40 and DC
Minimum intermediate licensing age 16½ or older	2	9 and DC
Night driving restriction once licensed	9	49 and DC
Passenger restriction once licensed	0	44 and DC

(9 p.m.–5:59 a.m.) occurrence, driver error, driver speeding, and single-vehicle crash involvement. Driver error was defined based on driver-related factors coded in FARS and was intended to capture the physical movements of the vehicle that were clearly indicative of driver mistakes (e.g., speeding, improper lane change, and passing on the wrong side). Codes for driver physical or mental conditions such as inattention, drowsiness, or alcohol impairment were excluded as these driver conditions are difficult for police officers to identify reliably. The BACs of fatally injured teenage and middle-aged drivers also were examined, with imputations for missing BACs provided by the U.S. Department of Transportation's multiple imputation model (Subramanian, 2002). Analyses focused on fatally injured drivers with positive BACs (i.e., BACs of any amount above zero) as all U.S. states and the District of Columbia prohibit people under 21 years of age from drinking alcohol and from driving with any detectable alcohol in their system. Drivers identified as speeding included cases in which the driver was cited for speeding or in which the driver-related factors included the driver traveling above the posted speed limit or too fast for conditions, or racing.

Per capita rates of fatal crashes and police-reported crashes were examined using population data from the U.S. Census. Rates of crashes also were derived per vehicle miles traveled. In-depth mileage data were obtained from the National Household Travel Survey (NHTS), formerly the Nationwide Personal Transportation Survey. NHTS collects information on travel from a nationally representative sample of U.S. households. The sample is weighted to provide national estimates of travel. Information on travel is collected for all members of each household so that travel can be estimated by mode (e.g., passenger vehicle, motorcycle, bicycle, public transportation, or walking), age, gender, time of day, and other factors. For the current study, data from the three most recent surveys (April 1995–March 1996, March 2001–April 2002, and 2008) were used to calculate drivers' fatal crash rates per 100 million miles driven and police-reported crash rates per 1 million miles driven. The first survey recorded travel at approximately the beginning of the study period, and the third survey provides travel data for a year near the end of the study period.

Ideally, rates of crashes per licensed driver would be examined, but there are no reliable current or historical national licensure data for teenagers. Although the Federal Highway Administration publishes annual state-by-state counts of driver licenses by age, examination of the data reveals large year-to-year fluctuations in a number of states in licensed driver counts for 16 year-olds, the minimum age of licensure in most states (Foss, 2013; Insurance Institute for Highway Safety [IIHS], 2006). These differences cannot be explained by fluctuations in population or changes in state licensing laws. NHTS asks whether household members drive but not their driver's license status, so that teenagers with learner's permits cannot be separated from those with intermediate or full driver's licenses.

3. Results

In 2012, there were 3071 drivers ages 16–19 involved in fatal crashes. Almost all were driving passenger vehicles (2897, or 94%), and a total of 3348 people died in their crashes. Of these deaths, 1313 (39%) were the 16–19-year-old drivers, 796 (24%) were their passengers, who often were teenagers, and 1238 (37%) were occupants of other vehicles, bicyclists, pedestrians, or other road users. An estimated 931,453 16–19-year-old passenger vehicle drivers were involved in police-reported crashes in 2012.

3.1. Profile of most recent crashes and crash rates

3.1.1. Crash risk per mile traveled in 2008

Fig. 1 shows the average number of passenger vehicle miles driven during 2008 by driver age and gender, based on the 2008 National Household Travel Survey. Among teenagers, the average amount of

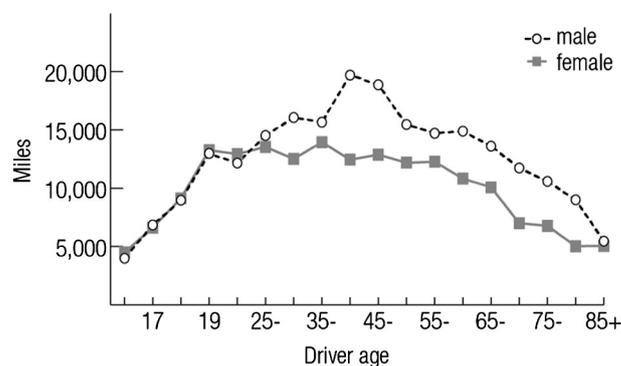


Fig. 1. Average number of passenger vehicle miles traveled by driver age and gender, 2008.

travel increased with age, from fewer than 5000 miles for 16 year-olds to about 13,000 miles for 19 year-olds. Drivers ages 16–18 logged far fewer miles, on average, than all but the oldest drivers. The average amount of travel was similar for male and female teenagers. In contrast, the average amount of travel for ages 30–84 was notably higher for males than for females.

Fig. 2 displays the rates of passenger vehicle driver fatal crash involvements per 100 million miles traveled in 2008 by driver age and gender. Among teenagers, rates for males were higher than rates for females, especially for 16 year-olds, and the rates for both males and females were highest at age 16, followed by age 17. The rate for 16-year-old male drivers (12.3 fatal crashes per 100 million miles traveled) was about twice the rate for 16-year-old female drivers (6.1), 9 times the rate for 30–59-year-old male drivers (1.3), and 12 times the rate for 30–59-year-old female drivers (1.0).

Per unit of travel, the rates of police-reported crashes of all severities in 2008 were highest for drivers ages 16–17; the rates for male and female 16–17-year-old drivers were 2–3 times as high as those for any other age group (Fig. 3). Teenagers' rates declined rapidly with age, falling from 31 crashes per million miles traveled for 16-year-old drivers to rates of 21 for 17-year-old drivers, 9.8 for 18-year-old drivers, and 9 for 19-year-old drivers. In contrast, the rate for drivers ages 30–59 was 3. The rate of police-reported crashes for 16-year-old drivers was higher for males than for females. Gender differences for drivers ages 17–19 were small.

Fig. 4 shows mileage-based rates of passenger vehicle driver involvements in fatal crashes during 2008 by driver age and time of day. For all age groups, fatal crash rates were higher at night (9 p.m.–5:59 a.m.) than during the day (6 a.m.–8:59 p.m.), but the difference was greatest for ages 16 and 17. The nighttime fatal crash rate was 4 times the daytime rate for 16-year-old drivers and 4.3 times the daytime rate for 17-year-old drivers.

Although the nighttime rates of police-reported crashes for teenage drivers were higher than their daytime rates (Fig. 5), the differences

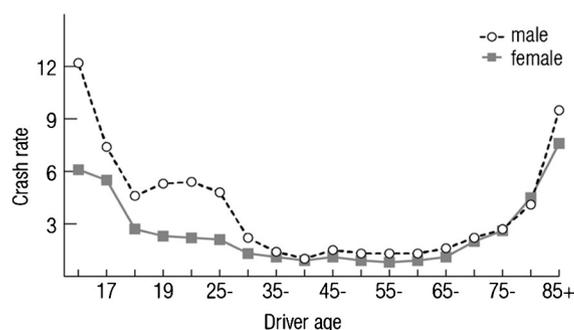


Fig. 2. Rates of passenger vehicle driver involvements in fatal crashes per 100 million miles traveled by age and gender, 2008.

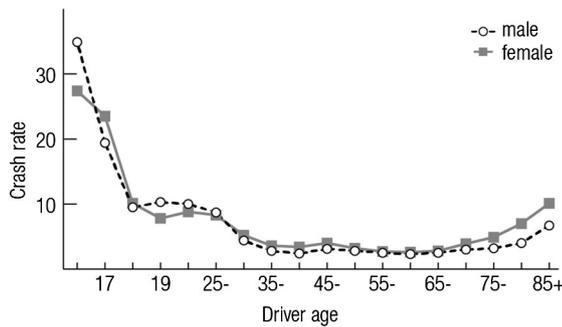


Fig. 3. Rates of passenger vehicle driver involvements in police-reported crashes per million miles traveled by age and gender, 2008.

were much smaller than the differences for fatal crash rates. The daytime and nighttime rates were about the same for 16-year-old drivers whereas the nighttime rate was 1.2 times the daytime rate for 17-year-old drivers.

3.1.2. Per capita crash risk in 2012

Table 2 summarizes the per capita rates of fatal crashes and police-reported crashes in 2012 for male and female teenage drivers and middle-aged drivers. Among teenagers, the per capita rates for both fatal crashes and police-reported crashes were generally higher for males than for females. However, in police-reported crashes the rate for 17-year-old driver involvements was lower for males (53 vs. 55 crashes per 1000 population), and both male and female 16 year-olds had rates of approximately 33 crashes per 1000 population. The rates for fatal and police-reported crashes among teenagers generally increased with age for males and for females. The per capita fatal crash rates for 17, 18, and 19 year-olds generally exceeded the rate for drivers ages 30–59 for males, females, and overall. The per capital fatal crash rates for 16 year-olds were lower than those for middle-aged drivers.

With regard to the per capita rates of police-reported crashes, the rate was lower for male 16 year-olds and about the same for female 16 year-olds when compared with the rates for 30–59-year-old males and females, respectively. The rates for other teenagers, both male and female, were much higher than the rates for 30–59 year-olds.

3.1.3. Characteristics of fatal crashes in 2012

Passengers accounted for 40% of 16–19-year-old passenger vehicle occupant deaths in 2012 (Table 3). The proportion of teenage deaths that were passengers generally declined with age; 46% of fatally injured 16 year-olds were passengers, compared with 32% of fatally injured 19 year-olds. In contrast, 19% of fatally injured 30–59-year-old passenger vehicle occupants were passengers.

Fifty-one percent of the deaths of teenage passengers ages 13–19 occurred in vehicles driven by a 16–19 year-old (table not shown). The proportion was even higher for 16-year-old passenger deaths,

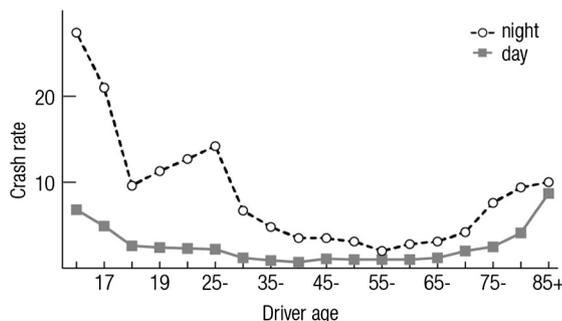


Fig. 4. Rates of passenger vehicle driver involvements in fatal crashes per 100 million miles traveled by age and time of day, 2008.

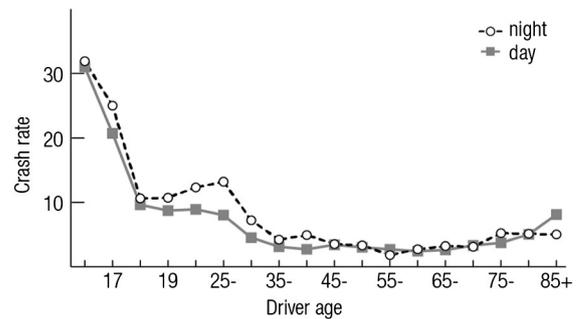


Fig. 5. Rates of passenger vehicle driver involvements in police-reported crashes per million miles traveled by age and time of day, 2008.

58% of which occurred when a 16–19 year-old was driving, and for 17-year-old passenger deaths, 66% of which occurred with a 16–19-year-old driver.

Fig. 6 shows the percentage of fatally injured passenger vehicle drivers with positive BACs (i.e., BACs of any amount greater than 0) by driver age and gender during 2012. At all ages, fatally injured male drivers were much more likely to have positive BACs than fatally injured female drivers. The percentage of fatally injured drivers with positive BACs generally increased throughout the teenage years for both males and females, and the percentage among teenagers was lower than among drivers ages 20–59. For both genders combined, the percentage of teenage drivers killed with positive BACs ranged from 15% for 16 year-olds to 31% for 19 year-olds, whereas 43% of 30–59-year-old fatally injured drivers had positive BACs. Similar patterns were observed when percentages of fatally injured drivers with BACs at or above 0.08% were examined (data not shown). All states and the District of Columbia have per se laws making it a crime to drive with a BAC at or above 0.08%.

Several characteristics of passenger vehicle driver involvements in fatal crashes in 2012 were examined by driver age and gender (Table 4). Among teenage drivers, the percentage of fatal crash involvements occurring at night (9 p.m.–5:59 a.m.) increased with age, ranging from 29% for 16 year-olds to 41% for 19 year-olds. Thirty percent of middle-aged drivers' fatal crash involvements occurred at night. The proportion of teenage drivers who were transporting two or more teenage passengers ages 13–19 decreased with age, ranging from 22% for 16 year-olds to 11% for 19 year-olds. Only about 1% of middle-aged drivers were transporting two or more teenage passengers.

Teenage drivers in fatal crashes, especially 16 year-olds, were more likely than drivers ages 30–59 in fatal crashes to have committed a driver error (which includes speeding), been speeding specifically, and been involved in a single-vehicle crash (Table 4). Among teenagers, the proportion of fatal crash involvements that involved a single vehicle showed an inconsistent pattern by age, whereas the proportion with driver error or speeding decreased with age.

For teenage drivers and middle-aged drivers alike, the crash characteristics were more likely to be present in the fatal crash involvements of male drivers than those of female drivers with only one exception. Female middle-aged drivers were slightly more likely to be transporting multiple teenage passengers than male middle-aged drivers.

Table 2

Rates of passenger vehicle driver involvements in fatal crashes and police-reported crashes per capita by driver age and gender, 2012.

Driver age (Years)	Drivers in fatal crashes per 100,000 population			Drivers in police-reported crashes per 1000 population		
	Male	Female	Total	Male	Female	Total
16	10.1	7.2	8.7	33.1	32.7	32.9
17	17.3	10.7	14.1	52.7	54.8	53.7
18	28.0	12.8	20.6	68.1	61.0	64.6
19	32.1	14.1	23.4	68.9	59.0	64.1
30–59	17.7	8.1	12.9	39.6	32.8	36.2

Table 3
Passenger vehicle occupant deaths by occupant age, 2012.

Occupant age (year)	Driver deaths	Passenger deaths	Total	Percent passengers
16	173	147	320	45.9
17	217	198	415	47.7
18	350	232	586	39.6
19	432	210	647	32.5
30–59	6825	1602	8447	19.0

Table 5 looks at the presence of driver error, speeding, single-vehicle involvement, and fatally injured drivers with positive BAC for passenger vehicle drivers ages 16–17 combined when the driver was alone, with one teenage passenger (and no adult passenger), or with two or more teenage passengers (and no adult passenger). The presence of each crash characteristic increased with one teenage passenger and even more so with two or more teenage passengers. For example, the percentage of teenage drivers who were speeding was 27% when the driver was alone, 40% when one teenage passenger was present, and 56% when two or more teenage passengers were present.

3.2. Changes in crash risk

3.2.1. Changes in crash risk per mile traveled

Fig. 7 shows changes in the average annual miles traveled by passenger vehicle drivers by driver age, based on the three most recent national household travel surveys. For drivers of all ages, the average number of miles traveled increased substantially from 1995–96 to 2001–02. The increase was somewhat smaller for teenagers and drivers 70 and older than for other ages. The average number of miles traveled declined from 2001–02 to 2008 for all ages, except ages 75–84, and the decline for drivers younger than 40 was larger than the decline for drivers ages 40–74. For ages 19 and older, the annual amount of travel increased from 1995–96 to 2008, whereas the average amount of travel for ages 16 and 17 declined slightly and the average amount of travel for 18 year-olds was essentially the same.

Across the three travel surveys, the rate of passenger vehicle driver involvements in fatal crashes per miles traveled varied little among ages 30–69, but there were consistent declines for drivers 70 and older (Fig. 8). For teenage drivers, the changes were inconsistent across the three survey years, but fatal crash rates declined noticeably from 1995–95 to 2008 for all teenage years.

The same general patterns by age were found for the rate of passenger vehicle driver involvements in police-reported crashes per million vehicle miles traveled (Fig. 9).

Table 6 summarizes the rates of crashes per mile traveled in 1995–96, 2001–02, and 2008 for teenagers and middle-aged drivers and the percentage changes from 1995–96 to 2008. The rate of fatal crashes per mile traveled fell by about one-third for 16, 18, and 19 year-olds, by 13% for 17 year-olds, and by one-quarter for ages 30–59. The rate of police-reported crashes per mile traveled declined by 12% for

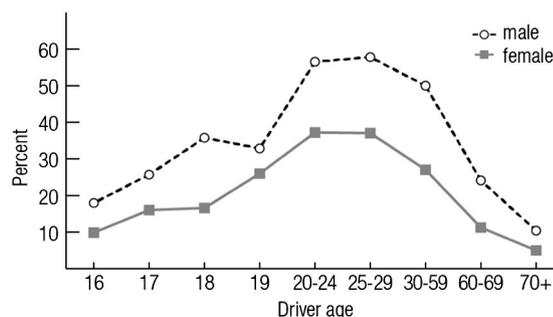


Fig. 6. Percentage of fatally injured passenger vehicle drivers with positive BACs by age and gender, 2012.

Table 4
Percentage of passenger vehicle driver involvements in fatal crashes with specific driver and crash characteristics by driver gender and age, 2012.

Driver age (years)	Driver gender		
	Male	Female	Total
Nighttime (9 p.m.–5:59 a.m.)			
16	32.7	22.4	28.6
17	31.4	29.7	30.9
18	39.2	32.2	37.1
19	42.5	37.1	40.9
30–59	34.1	22.7	30.5
2 or more teenage passengers			
16	25.8	17.0	22.3
17	19.5	14.0	17.6
18	18.2	16.3	17.6
19	12.4	7.3	10.9
30–59	1.0	2.1	1.4
Single vehicle crash			
16	50.7	46.9	49.2
17	50.4	39.6	46.3
18	50.4	41.1	47.6
19	51.9	40.7	48.6
30–59	42.3	34.2	39.7
Driver error			
16	72.8	67.3	70.6
17	65.2	59.5	63.0
18	62.4	55.9	60.4
19	60.8	50.7	57.8
30–59	42.5	37.4	40.9
Driver speeding			
16	43.3	32.0	38.7
17	36.4	27.0	32.9
18	35.7	23.3	32.0
19	34.7	20.2	30.5
30–59	20.2	12.9	17.9

16 year-olds, 36% for 18 year-olds, 43% for 19 year-olds, and 27% for 30–59 year-olds, whereas there was a negligible change in the rate for 17 year-olds.

3.2.2. Changes in per capita crash risk

The per capita rates of fatal crash involvements for teenage drivers and for drivers ages 16, 17, 18, 19, and 30–59 for the years 1975–2012 are displayed in Fig. 10. The rates for middle-aged drivers generally followed a slow decline and then a somewhat sharper decline beginning in 2008. The rates for teenagers experienced gradual fluctuations until the mid-1990s, after which the rates declined sharply.

Fig. 11 shows the annual per capita rates of police-reported crashes for these age groups beginning in 1988, when national samples became available, through 2012. Given the relatively small sample of crashes involving teenage drivers, there is more year-to-year variability in the rates of police-reported crashes for teenagers than in their rates of fatal crashes. Generally, however, the changes for police-reported crash rates are similar to the changes for fatal crashes for both middle-aged drivers and teenage drivers. Whereas crash rates for middle-aged drivers showed a gradual decline during 1996–2012, crash rates for teenage drivers generally showed a sharp decline beginning in the mid-1990s.

Table 7 summarizes the per capita crash rates in 1996, 2005, and 2012 for teenage and middle-aged drivers and the percentage changes

Table 5
Percentage of 16–17-year-old passenger vehicle driver involvements in fatal crashes with specific driver and crash characteristics by number of teenage passengers, 2012.

Crash characteristic	Driver alone	One teenage passenger only	Two or more teenage passengers only
Driver error	62.3	69.7	78.7
Speeding	26.7	40.3	55.6
Single vehicle	40.3	55.9	59.2
Drivers killed with positive BACs	12.4	14.8	19.5

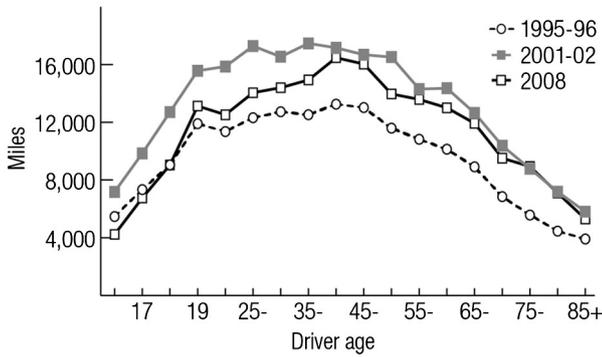


Fig. 7. Average annual miles traveled by passenger vehicle drivers by age, 1995–96, 2001–02, and 2008.

between 1996 and 2012. There were declines between 1996 and 2012 in the fatal crash rates for all ages, but the declines were larger for teenage drivers (45–74%) than for middle-aged drivers (34%). Among teenagers, declines were largest for 16 year-olds (74%), followed by 17 year-olds (64%), 18 year-olds (56%), and 19 year-olds (45%). The same pattern was seen in the per capita rate of police-reported crashes. Declines between 1996 and 2012 for teenagers ranged from 65% for 16 year-olds to 35% for 19 year-olds. The decline for ages 30–59 was 33%.

3.3. Changes in fatal crash characteristics

Fig. 12 plots the percentage of fatally injured passenger vehicle drivers with positive BACs from 1982, when imputed BAC data became available in FARS, to 2012 for the study groups. Large declines occurred for all age groups from 1982 to the mid-1990s, with declines especially strong for teenagers. Since 1996, the rate of positive BACs was fairly consistent among 30–59 year-olds. There was more year-to-year variability among teenagers. From 1996 to 2012, the rates decreased for teenagers, with declines ranging from 3% for 18 year-olds to 20% for 16 year-olds.

Table 8 shows several characteristics of passenger vehicle driver involvements in fatal crashes for teenagers and ages 30–59 during the years 1996, 2005, and 2012, as well as the percentage change between 1996 and 2012.

As noted above, all state GDL programs but one have nighttime restrictions for teenagers with intermediate licenses, and 44 states and the District of Columbia restrict the number of teenage passengers that can be transported by intermediate license holders. Thus, it would be expected that the percentage of fatal crashes occurring at night or with multiple teenage passengers present would have declined during the study period for 16 year-olds, the drivers most likely to have an intermediate license, and for 17 year-olds to a lesser extent. As shown in Table 8, the percentage of fatal crash involvements among teenage drivers occurring at night declined from 1996 to 2005 and again in 2012. The percentage decline from 1996 to 2012 was 11% for

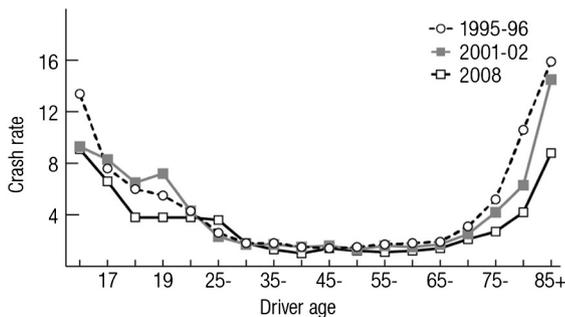


Fig. 8. Rates of passenger vehicle driver involvements in fatal crashes per 100 million miles traveled by age, 1995–96, 2001–02, and 2008.

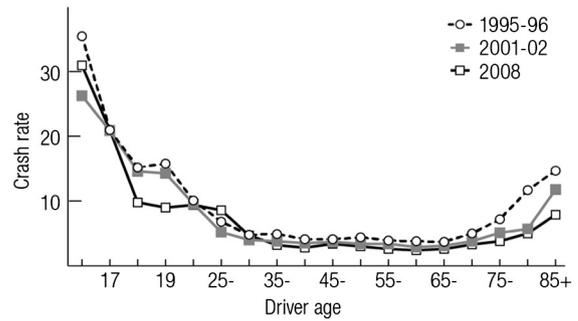


Fig. 9. Rates of passenger vehicle driver involvements in police-reported crashes per million miles traveled by age, 1995–96, 2001–02, and 2008.

16 year-olds, 13% for 17 year-olds, 10% for 18 year-olds, and 7% for 19 year-olds. In contrast, middle-aged drivers experienced a 7% increase. The proportion of drivers involved in fatal crashes who were transporting two or more teenage passengers declined from 1996 to 2012 for 16 year-olds (20%), 17 year-olds (17%), and 19 year-olds (16%), with most of the declines occurring between 1996 and 2005. Among 18-year-old drivers, the proportion increased by 4%. Less than 2% of middle-aged drivers were transporting two or more teenage passengers in any of the study years.

The percentage of fatal crash involvements involving driver error declined from 1996 to 2012 for all age groups (Table 8). The size of the declines increased with age and ranged from 6% for 16 year-old drivers to 18% for middle-aged drivers. The percentage of fatal crash involvements involving speeding increased by 7% among 16 year-olds, whereas the percentage decreased slightly among other teenagers and increased slightly among middle-aged drivers. The percentage of fatal crash involvements that were single-vehicle crashes increased for all age groups.

4. Discussion

Teenage drivers' crash risk has declined since 1996, when Florida implemented the first graduated licensing program in the United States. However, mileage-based crash risk still remains substantially higher for teenagers than that for middle-aged drivers, and rates are much higher for 16 year-olds and 17 year-olds than for older teenagers. Since 1996, all states and the District of Columbia have implemented GDL laws, and many states have strengthened their original laws. Although the current study is not a rigorous examination of the effects of graduated licensing programs on the crash risk of teenage drivers, the findings are consistent with the increasing presence of these laws. The current study shows that from 1996 to 2012, there were steady, steep declines in teenagers' per capita fatal crash involvement rates and police-reported crash involvement rates. The declines among

Table 6 Rates of passenger vehicle driver crash involvements per mile traveled by driver age, 1995–96, 2001–02, and 2008.

Driver age (years)	1995–96	2001–02	2008	Percent change 2008 vs. 1995–96
Rate of fatal crashes per 100 million miles traveled				
16	13.4	9.3	9.1	–32.5
17	7.6	8.3	6.6	–12.8
18	6.0	6.5	3.8	–36.8
19	5.5	7.2	3.8	–31.1
30–59	1.6	1.6	1.2	–24.6
Rate of police-reported crashes per 1 million miles traveled				
16	35.5	26.3	31.0	–12.5
17	21.0	20.9	21.0	–0.1
18	15.2	14.6	9.8	–35.8
19	15.8	14.3	9.0	–43.0
30–59	4.4	3.7	3.2	–27.5

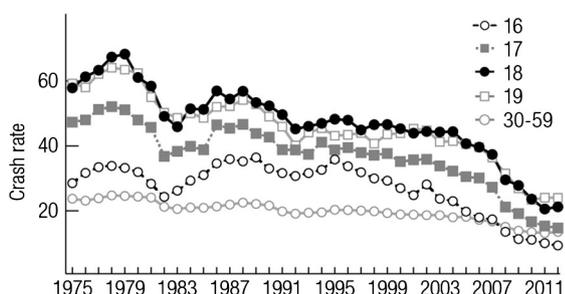


Fig. 10. Rates of passenger vehicle driver involvements in fatal crashes per 100,000 people by age, 1975–2012.

teenagers were larger than the declines among middle-aged drivers, and declines for all ages were largest during the economic downturn beginning in 2007–08. The declines were most dramatic among young teenagers, the ages most directly affected by graduated licensing. Rates of teenagers' fatal crash involvements and police-reported crash involvements per mile traveled declined from 1995–96 to 2008, and declines generally were larger than those for middle-aged drivers. The declines among teenagers were smaller than the declines in per capita fatal crash rates, especially for younger teenagers.

The much stronger and more consistent declines in crash rates per capita compared with crash rates per vehicle miles traveled among younger teenagers could reflect in part the reduction in the average amount of driving among younger teenage drivers reported in the current study. They also could reflect overall reductions in driving due to delays in licensure resulting from GDL, economic factors, or other unknown reasons. Delays in licensure would have occurred in states that implemented laws that delayed the minimum age of licensure, and learner's permit requirements also may have slowed down licensure indirectly. In recent years, there is evidence that licensure among young teenagers has declined, with the economic downturn as a key factor (Highway Loss Data Institute, 2013; Shults & Williams, 2013). The current study used the National Household Travel Survey to derive changes in the amount of driving for teenage and adult drivers. It is important to note that the last travel survey estimated travel patterns during 2008, whereas the economic downturn in the United States extended beyond 2008. Thus, the totality of any effects of the economic downturn on licensing among teenagers or driving patterns among teenagers and adults, and the resulting effects on the rates of crashes per miles driven, would not be captured in the current study.

Progress in reducing the prevalence of identified risk factors in teenagers' fatal crashes between 1996 and 2012 was mixed. There were declines in the proportion of younger teenagers' fatal crash involvements occurring at night and with two or more teenage passengers. This is consistent with the implementation of laws with restrictions on nighttime driving and teenage passengers during the intermediate license stage and research showing the effectiveness of these restrictions in reducing crashes (e.g., McCartt et al., 2010). Still, transporting teenage passengers and driving at night remain important

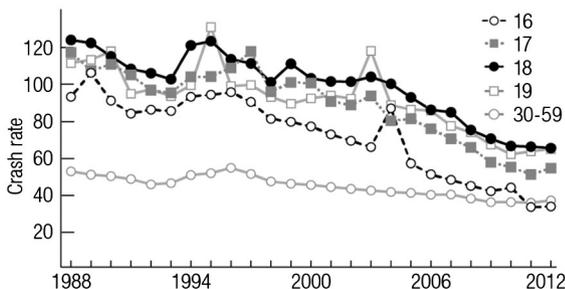


Fig. 11. Rates of passenger vehicle driver involvements in police-reported crashes per 1000 population by age, 1988–2012.

Table 7

Rates of passenger vehicle driver crash involvements per capita by driver age, 1996, 2005, and 2012.

Driver age (years)	1996	2005	2012	Percent change 2012 vs. 1996
Rate of fatal crashes per 100,000 population				
16	33.1	19.1	8.7	−73.7
17	38.9	29.9	14.1	−63.7
18	47.3	40.1	20.6	−56.4
19	42.8	40.0	23.4	−45.3
30–59	19.6	17.5	12.9	−34.2
Rate of police-reported crashes per 1000 population				
16	95.0	56.3	32.9	−65.3
17	108.1	80.5	53.7	−50.3
18	112.9	92.2	64.6	−42.8
19	98.3	85.6	64.1	−34.8
30–59	53.9	40.3	36.2	−32.8

factors in the fatal crashes of teenagers, and many states' GDL laws could be strengthened in this regard. It is concerning that many teenage passenger deaths continue to occur in vehicles driven by teenage drivers. Future research might focus on the extent to which this reflects the amount of travel by teenagers as passengers with peers. There is little research on the patterns of travel as a passenger by age or on how the risk of being in a crash as a passenger varies with driver age.

There also were declines in the percentage of fatally injured teenage drivers with positive BACs, although it should be noted that year-to-year variation in the prevalence of positive BACs among fatally injured teenage drivers is common.

The proportion of teenage drivers in fatal crashes with driver errors declined, but less so than for middle-aged drivers. Consistent with other recent research (Ferguson, 2013), the proportion of teenagers' fatal crash involvements involving speeding increased among 16 year-olds, whereas the percentage decreased slightly among other teenagers and increased slightly among middle-aged drivers. The proportion of teenage drivers in fatal crashes who were speeding increased markedly with the presence of teenage passengers. Thus, although speeding is not addressed directly by GDL laws, strong restrictions on driving at night and with teenage passengers may help reduce speeding. In addition, there is some evidence that in-vehicle monitoring devices can be effective in reducing teenage drivers' speeding behaviors (Farmer, Kirley, & McCartt, 2010).

Recent attention has focused on whether stronger GDL laws may have been associated with increases in crash rates among older teenagers. There is mixed evidence about this possibility (Masten et al., 2011; McCartt et al., 2010; Trempe, 2009). The current study found large and consistent declines among older teenagers in both the mileage-based and the population-based rates of fatal and police-reported crashes during the period when graduated licensing programs have been implemented, and often strengthened, across the country. These findings are largely consistent with the findings of Williams (2014), who examined the fatal crash involvement rates of teenage drivers during 1990–2011, relative to the rates of 25–59 year-olds.

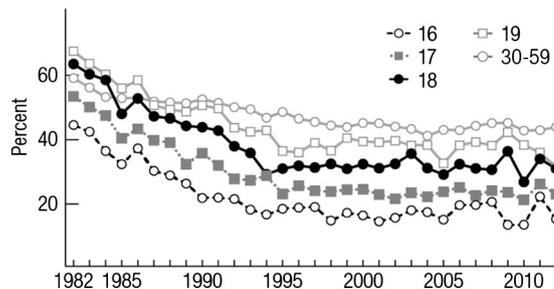


Fig. 12. Percentage of fatally injured underage passenger vehicle drivers with positive BACs by age, 1982–2012.

Table 8
Percentage of passenger vehicle driver involvements in fatal crashes with driver and crash characteristics by driver age, 1996, 2005, and 2012.

Crash characteristics	1996	2005	2012	Percent change 2012 vs. 1996
16 year-old drivers				
Nighttime (9 p.m.–5:59 a.m.)	32.2	29.0	28.6	–11.4
2 or more teenage passengers	27.7	22.9	22.3	–19.8
Single vehicle	47.0	49.0	49.2	4.7
Driver error	75.1	74.9	70.6	–6.0
Speeding	36.2	35.1	38.7	6.9
17 year-old drivers				
Nighttime (9 p.m.–5:59 a.m.)	35.6	35.4	30.9	–13.1
2 or more teenage passengers	21.3	17.6	17.6	–17.4
Single vehicle	45.0	46.7	46.3	2.9
Driver error	69.9	73.5	63.0	–10.0
Speeding	33.0	32.9	32.9	–0.4
18 year-old drivers				
Nighttime (9 p.m.–5:59 a.m.)	41.2	40.1	37.1	–9.9
2 or more teenage passengers	16.9	14.6	17.6	4.4
Single vehicle	45.3	43.7	47.6	5.1
Driver error	69.4	71.4	60.4	–12.8
Speeding	32.3	33.6	32.0	–0.9
19 year-old drivers				
Nighttime (9 p.m.–5:59 a.m.)	43.9	41.7	40.9	–6.9
2 or more teenage passengers	13.0	11.3	10.9	–16.0
Single vehicle	46.8	45.6	48.6	4.0
Driver error	66.8	69.4	57.8	–13.4
Speeding	30.8	34.1	30.5	–1.1
Drivers ages 30–59				
Nighttime (9 p.m.–5:59 a.m.)	28.4	28.7	30.5	7.3
2 or more teenage passengers	1.6	1.7	1.4	–11.8
Single vehicle	35.3	36.3	39.7	12.4
Driver error	50.0	49.3	40.9	–18.3
Speeding	17.6	17.0	17.9	1.4

There were reductions in younger teenagers' crash rates occurring during an early GDL period of 1997–02 and a later GDL period of 2003–07, relative to a pre-GDL period of 1990–96, but no evidence of increases or decreases in older teenagers' crash rates.

As reported in the current study, the most recent data suggest that the rates of fatal crash involvements per capita and per vehicle miles traveled are much higher for older teenagers than for middle-aged drivers. The issue of whether GDL requirements should be applied to novice drivers 18 and older is receiving increased attention (Governors Highway Safety Association, 2012). In New Jersey, which applies graduated licensing restrictions to all initial license holders younger than age 21 and where an intermediate license is not available until age 17, significant reductions in the crash rates for 16, 17, and 18 year-olds were found without adversely affecting the crash rates for 19 year-olds (Williams, Chaudhary, Tefft, & Tison, 2010).

The national data on police-reported crashes are based on a nationally representative sample. It is worth noting that the data cover a wide range of crash severities, from crashes resulting in property damage only to crashes resulting in serious injury or even death. The completeness and accuracy of crash reports vary across jurisdiction. In addition, sample sizes can be small when crashes for individual years of age or narrow age categories are examined, which can lead to large year-to-year fluctuations. It would have been useful to compare changes in the rates of crashes of different severities for teenage drivers and adult drivers, but this is not possible given the small sample of crashes involving teenage drivers. The coding of injury severity by police officers also can be imprecise.

5. Implications

The current study adds to the research on teen driver safety in the United States by providing an updated detailed profile of teenagers' crash risk, based on the most current data available, and an overview of changes in teenagers' crash risk over the past two decades. Teenagers'

crash risk is substantially lower than it used to be, although still higher than for adults.

It is likely that a major factor in this decline was the enactment of GDL programs, which have been associated with reductions in crashes in numerous studies (Shope & Molnar, 2007; Williams & Shults, 2010; Williams, Tefft, & Grabowski, 2012). Some researchers have found increases in the fatal crash rates of 18 year-olds associated with stronger GDL laws (Masten et al., 2011), but the current study found no evidence of increased crash risk among older teenagers since GDL laws have been implemented.

Further gains can be achieved through the strengthening of current GDL programs. Based on research examining the effects on rates of teenagers' fatal crashes and insurance collision claims associated with specific GDL components (McCartt et al., 2010; Trempe, 2009), the effects of changing individual provisions of graduated licensing have been estimated for each state. The information is available via an online crash reduction calculator (www.iihs.org/gdl). It is estimated that some states could halve or more than halve their rates of fatal crashes among 15–17 year-olds if they adopted the strongest GDL provisions that currently exist in the United States (McCartt et al., 2010). Based on the success of graduated licensing for the youngest drivers in reducing crashes, requiring GDL for older teens likely would reduce their crash and injury risks as well.

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