

An Evaluation of the Effect of Ohio's Graduated Driver Licensing Law on Motor Vehicle Crashes and Crash Outcomes Involving Drivers 16 to 20 Years of Age

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ABSTRACT

Importance: Nationally, motor vehicle crashes are the leading cause of death among teens and young adults ages 15 to 20 years. Graduated driver licensing (GDL) laws have been implemented to reduce motor vehicle crashes among teen drivers by providing a learning period for teens to gain experience driving a motor vehicle under lower-risk conditions.

Objective: To evaluate the effects of Ohio's 2007 updated GDL law on motor vehicle crashes, crash-related injuries, and hospital resource utilization for crashes involving teen drivers ages 15.5 through 20 years, with a focus on the effects on crashes involving drivers ages 18 through 20 years.

Design, Setting, and Participants: Cross-sectional analysis of motor vehicle crashes involving drivers ages 15.5 through 20 years in Ohio in the pre-GDL (2004-2006) and post-GDL (2008-2010) periods.

Main Outcome Measures: Descriptive statistics and population-based crash rates for drivers ages 16 through 20 years. Odds ratios, rate ratios and 95% CIs comparing covariates associated with crashes in the pre-GDL and post-GDL periods.

Results: Compared with the pre-GDL period, overall crash, injury crash and fatal crash rates were lower in the post-GDL period for all teen driver age groups.

Drivers age 16 years had the greatest declines in overall crash involvement rate (-34.5%) and injury crash rate (-37.9%) while drivers age 19 years (-43.8%) and 20 years (-42.3%) had the largest declines in fatal crash rate. The post-GDL period was associated with lower crash rates for drivers age 16 years (RR=0.94 [95% CI=0.90-

0.98]), age 17 years (RR=0.90 [95% CI=0.88-0.93]), age 18 years (RR=0.95 [95% CI=0.92-0.97]) and ages 16 to 17 years combined (RR=0.92 [95% CI=0.90-0.95]). Crash rate was higher for the post-GDL period for drivers age 19 years (RR=1.04 [95% CI=1.01-1.07]), age 20 years (RR=1.09 [95% CI=1.05-1.13]) and ages 18 to 20 years combined (RR=1.02 [95% CI=1.00-1.03]).

Conclusions: The post GDL-period was associated with lower crash, injury crash, and fatal crash involvement among drivers and occupants ages 16 to 17 years, but higher overall crash involvement for drivers and occupants ages 19 years, 20 years and 18 to 20 years combined. The results support extending GDL restrictions to older novice drivers as a promising strategy for reducing crashes among older teen drivers.

INTRODUCTION

Nationally, motor vehicle crashes are the leading cause of death among teens and young adults ages 15 to 20 years.¹ From 2002 to 2012, more than 31,000 drivers and over 18,000 passengers ages 16 to 20 years were killed in motor vehicle crashes.² In Ohio, drivers 16 to 25 years of age were involved in 46.8% of injury crashes during 2005-2007.³

Graduated driver licensing (GDL) laws have been implemented in all 50 states to reduce motor vehicle crashes among teen drivers. GDL laws are designed to decrease crashes by providing a learning period for teens to gain experience and skills behind the wheel of a motor vehicle under lower-risk conditions, and thereby, delaying the acquisition of a full driver license. Driving experience clearly plays a role in teen crashes. Motor vehicle crash rates among novice teen drivers drop most dramatically during the first six months of driving.⁴ Although the advantages of restricted driving and delaying full licensure were initially identified almost 30 years ago, the first GDL law was not enacted in the US until 1996.^{5,6}

Originally passed in October 1997, and further revised in April 2007 to include stricter nighttime driving and passenger limitations, Ohio's GDL law creates three tiers of driver licensing: temporary permit, probationary license, and full license. A temporary permit may be obtained at age 15 ½ years, and is the initial learning stage, requiring extensive driver training and supervision. After at least six months, a temporary permit holder in Ohio is eligible to advance to the second tier, the probationary driver license, if he or she is at least age 16 years and has completed the driving training certification requirement. The permit holder must also complete a state driving and maneuverability

test prior to issuance of a probationary driver license. The probationary license phase includes restrictions on nighttime driving and passenger limitations. Holders of a probationary license may be subject to additional restrictions if they commit a moving violation within the first six months after receiving the license. Ohio law applies more stringent suspension and revocation provisions to holders of temporary permits and probationary licenses than it does to holders of full driver licenses. The probationary license is valid until age 18 years, at which time the license becomes a full driver license.⁷⁻⁹ Provisions and minimum requirements for obtaining licensure under the Ohio GDL law are shown in **Table 1**.

GDL laws have clearly been effective in reducing teen crash rates. Studies have shown decreases in teen crash rates of 20%-40% following enactment of GDL laws, as well as declines in the rate and number of teen motor vehicle crash-related fatalities.¹⁰⁻¹² In addition, studies comparing states with GDL laws of varying strengths have found that stronger laws produce greater reductions.^{11,13-15} However, despite the advances, drivers ages 16 to 19 years continue to have a crash rate per vehicle-mile driven that is 4-fold higher and a fatal crash rate that is 2-fold higher than those for older drivers.¹⁶

Both nighttime driving restrictions and passenger limitations have decreased teen mortality associated with motor vehicle crashes.^{17,18} Using FARS data, a study by Masten, et al. (2011) examined fatal crashes among 16 to 19 year old drivers in all 50 states over an 11-year period and found a 26% lower fatal crash rate involving 16-year old drivers in states with nighttime driving and passenger restrictions compared with states with neither restriction. However, the study also uncovered a 12% increase in the fatal crash rate among 18-year old drivers in these same states. Indeed, the fatal crash

rate for 16-19 year-olds overall showed no statistically significant difference between states with and without restrictions.¹⁹ The study authors speculate that the increase among 18 year old drivers may be due in part to teens waiting until their eighteenth birthday to obtain a driver license, and thus bypassing a learning period under the restrictions of GDL.¹⁹ In addition, fatal motor vehicle crashes are a unique subset of all motor vehicle crashes, and are more commonly associated with high-risk behaviors, such as high speed and alcohol consumption, than non-fatal crashes.²⁰ GDL is designed to provide experience to novice drivers under lower-risk conditions and does not address excessive risk-taking and other extreme behaviors.¹⁹ The extension of GDL to older teen drivers has been proposed. Currently, New Jersey applies GDL restrictions to all initial driver license applicants younger than age 21 years. An evaluation of the New Jersey law has demonstrated benefits among 16- to 18-year-olds without resulting untoward effects among 19-year old drivers.²¹ The true effect, if any, GDL laws have on older teen drivers and whether these programs should be extended to include older teens are still unclear and warrant further study.¹⁶ In their conclusions, Masten and colleagues recommend that single-state studies of GDL effectiveness include less severe crashes, better control for state-specific factors, and examine crashes for all ages from 16 through 19 years in order to fully estimate the effect of GDL on teenage crashes.¹⁹

The current study evaluated the effects of Ohio's 2007 updated GDL law on motor vehicle crashes, motor vehicle crash-related injuries, and the utilization of medical resources associated with these injuries for crashes involving teen drivers ages 15 ½ through 20 years. We compared the pre-GDL (2004-2006) period to the post-GDL

(2008-2010) period using linked and unlinked statewide data, with a focus on the effects of the GDL law on crashes involving drivers ages 18 to 20 years. Unlike previous studies, this study examined the outcomes of all occupants in injury and non-injury crashes involving drivers ages 16 to 20 years, and is the first to examine the effect of a GDL law on healthcare resource utilization associated with injured occupants.

METHODS

Data sources

This investigation used three large statewide databases for Ohio. The Ohio Department of Public Safety crash database contains all reported crash incidents that involve an injury or property damage in excess of \$400. Approximately 350,000 crashes are reported to this database by Ohio law enforcement agencies annually.

The Ohio Hospital Association database includes all emergency department (ED) and inpatient admissions reported by the approximately 174 member hospitals. Approximately 4.5 million ED visits and 1.6 million inpatient admissions are reported to this database annually. Records containing a diagnosis code in the range of 800.00-960.00 or an E-code indicating an external cause of injury (E800-E999, or V714) according to the 9th Revision of the International Classification of Diseases, Clinical Modification (ICD-9-CM) were selected for data linkage.

The Ohio trauma registry is a database that contains detailed information on all injured patients admitted to an Ohio hospital for 48 hours or longer, injured patients who died at any point during their treatment, and injured patients who were transferred into

or out of a hospital for further trauma care. Approximately 35,000 trauma admissions are reported to the database annually.

The Ohio crash database, Ohio hospital database and Ohio trauma registry for the years 2004 through 2006 (prior to implementation of stricter GDL) and 2008 through 2010 (after implementation of stricter GDL) were probabilistically linked using CODES2000 software (Strategic Matching, Inc., Morrisonville, NY) to create a combined research data set for analysis. The probabilistic linkage procedure includes multiple imputation of missing links to reduce potential bias in the combined research data set.²²⁻

²⁴ The study population included occupants in motor vehicle crashes involving drivers ages 15 ½ -20 years, and who were identified as an occupant (Ohio crash database) and/or received treatment in an ED or as a hospital inpatient for a motor vehicle-crash related injury (emergency department and inpatient hospital dataset, trauma registry). The study period was the three years (2004-2006) prior to implementation of the stricter GDL standards of the 2007 GDL law in Ohio and the three years (2008-2010) following implementation.

Variables in this study were derived from information contained in police reports and/or hospital records. An individual was considered injured if either the police report or hospital record indicated an injury. For those individuals with a linked hospital record, the primary cause of injury was defined as the first-listed E-code in the hospital record. For individuals involved in motor vehicle crashes without a linked hospital record, a death was said to have occurred if the police report indicated a fatality. For those with a linked hospital record, a death was said to have occurred if hospital discharge

information indicated a fatality. Counts for number of injured individuals includes those with fatal injuries.

Hospital care and resource utilization information, including length of stay and hospital charges, were only available for injured individuals with a linked hospital record. Barell Matrix classification from injury diagnosis codes was used to determine the nature of injury (e.g., fracture) and body region injured (e.g., torso).²⁵ Injury Severity Score (ISS) was determined from injury diagnosis codes using ICDMAP-90 software.²⁶ In order to make more accurate comparisons, hospital charges were adjusted for inflation using the Hospital Services Consumer Price Index (CPI) published by the Bureau of Labor Statistics.²⁷ All estimates of charges presented in this report are in 2010 dollars.

Descriptive crash and occupant information, such as gender, age, restraint use, motor vehicle type (passenger car, van/mini-van, pickup, sports utility vehicle [SUV], other, non-motor vehicle), collision type (frontal, side, rear, other), vehicle speed, and light, road and weather conditions was obtained from the crash report. Driver age was dichotomized into 16 to 17 year-olds and 18 to 20 year-olds for some analyses. Collisions involving two or more vehicles with at least one driver in each age category (16 to 17 and 18 to 20 year-olds) were included in counts for both age groups. In the pre-GDL period, there were 8,623 such crashes and in the post-GDL period, there were 5,715 such crashes. The variables for adverse light, road, and weather conditions, such as dusk, rain, sleet, fog, or other conditions that existed at the time of the crash were dichotomized, indicating the presence or absence of adverse conditions. Crash variables for day of the week and time of day were used to create a dichotomous

variable for weekend. Weekend was defined as the period from 5:00 p.m. Friday through 4:59 p.m. Sunday, similar to the social weekend definition used by Carpenter and Pressley in their study on nighttime GDL compliance.²⁸ A summer crash was defined as one occurring during the months of June, July or August. Alcohol use, restraint use, and speeding were dichotomized as presence or absence of the condition. Number of passengers was calculated as the number of occupants minus one (the driver). Youth passengers were defined as those passengers age 25 years or younger, as studies have shown that older teens and young adults increase both access to alcohol and crash risk for younger teen drivers.²⁸⁻³⁰ Metropolitan area was determined from crash county and US Department of Agriculture definitions of metropolitan and non-metropolitan counties.³¹ Primary outcome measures, including length of hospital stay and inflation-adjusted total hospital charges, as well as secondary outcome measures, including admission to the hospital (yes/no) and admission to a rehabilitation facility (yes/no), were obtained from the hospital record. Inpatient counts do not include ED patients. The trauma registry was used to provide additional data, including admission to the intensive care unit (ICU; yes/no) and use of mechanical ventilation (yes/no).

Data Analysis

Descriptive statistics (frequencies, means, medians, ranges) were calculated for relevant crash and injury variables. Chi-squared tests were used to assess statistical significance ($p \leq 0.05$) of categorical variables between the pre-GDL and post-GDL periods. Logistic and linear regression model analyses were conducted to determine the

influence of selected risk/protective factors on crash occupants' health and economic outcomes. Crash, injury and fatality rates based on age-specific populations were computed using US census data for the state of Ohio.³²

Because the US Census Bureau does not provide population estimates for half-years of age, and due to the fact that the 2007 changes to Ohio's GDL law applied only to drivers 16 and 17 years of age, we opted to include only drivers ages 16 and 17 years and their occupants in regression analyses and rate calculations for the younger age group.

Poisson regression models were used to estimate overall crash involvement, injury crash, and fatal crash rate ratios for 16 to 17 year old and 18 to 20 year old drivers. In addition, Poisson regression models were used to estimate rate ratios among teen occupants in crashes with at least one driver 16 to 20 years of age. Rate ratios compared the post-GDL law period (2008-2010) with the period prior to the 2007 GDL law (2004-2006). The natural logarithm of the state population was used as an offset term in the models to account for exposure.³³ Regression models included variables to adjust for confounding, including Ohio annual gasoline prices, Ohio highway fuel use, and Ohio annual vehicle-miles of travel.^{34,35}

IVEware (University of Michigan, Ann Arbor, MI) was used to conduct multiple imputation of missing values, resulting in five imputed data sets for analyses.³⁶ All analyses were performed with SAS version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

Study population

In the period prior to implementation of stricter GDL standards (2004-2006), there were 218,338 crashes involving one or more drivers ages 15.5 to 20 years. There were 567,084 occupants involved in these crashes, of which 321,479 (56.7%) were ages 15 to 20 years. Of these, 231,463 were drivers ages 15.5 to 20 years (230,395 were drivers ages 16 to 20 years).

In the post-GDL period (2008-2010), there were 169,013 crashes involving one or more drivers ages 15.5 to 20 years. There were 436,701 occupants involved in these crashes, of which 245,212 (56.1%) were ages 15 to 20 years. Of these, 177,593 were drivers ages 15.5 to 20 years (176,910 were drivers ages 16 to 20 years).

Crash, injury crash and fatal crash rates among drivers

Table 2 presents age-specific and combined age group crash, injury crash and fatal crash rates per 100,000 population for drivers ages 16 to 20 years by GDL period. Overall crash, injury crash and fatal crash rates were consistently lower in the post-GDL period compared to the pre-GDL period for all teen driver age groups. Drivers age 16 years had the greatest declines in overall crash involvement rate (-34.5%) and injury crash rate (-37.9%) from the pre-GDL period to the post-GDL period. The largest declines in fatal crash rate were noted among drivers ages 19 years (-43.8%) and 20 years (-42.3%), while drivers ages 16 years had the smallest decline in fatal crash rate (-27.3%) between the pre-GDL and post-GDL periods.

Adjusted rate ratios comparing crash involvement, injury crash and fatal crash rates post-GDL with rates during the pre-GDL period among drivers ages 16 to 20 years after adjusting for factors including highway fuel use, gas prices and vehicle-miles of

travel are reported in **Table 3**. The post-GDL period was statistically associated with lower crash involvement rates for drivers age 16 years (RR=0.94 [95% CI=0.90-0.98]), age 17 years (RR=0.90 [95% CI=0.88-0.93]), age 18 years (RR=0.95 [95% CI=0.92-0.97]) and for drivers ages 16 to 17 years combined (RR=0.92 [95% CI=0.90-0.95]). The crash involvement rate was statistically higher for the post-GDL period than for the pre-GDL period for drivers age 19 years (RR=1.04 [95% CI=1.01-1.07]), age 20 years (RR=1.09 [95% CI=1.05-1.13]) and for drivers ages 18 to 20 years combined (RR=1.02 [95% CI=1.00-1.03]). The post-GDL period was statistically associated with lower injury crash rates for drivers age 16 years (RR=0.86 [95% CI=0.80-0.93]), age 17 years (RR=0.89 [95% CI=0.84-0.94]), age 18 years (RR=0.87 [95% CI=0.83-0.91]), and for drivers ages 16 to 17 years combined (RR=0.89 [95% CI=0.85-0.93]) and 18 to 20 years combined (RR=0.96 [95% CI=0.93-0.99]). The post-GDL period was statistically associated with lower fatal crash rates for drivers age 17 years (RR=0.47 [95% CI=0.23-0.92]), age 18 years (RR=0.47 [95% CI=0.26-0.82]) and for drivers ages 18 to 20 years combined (RR=0.65 [95% CI=0.46-0.93]).

Occupant characteristics

The population characteristics of occupants in motor vehicle crashes involving one or more drivers ages 16 to 20 years by driver age group and GDL period are shown in **Table 4**. The total number of occupants involved in crashes in the post-GDL period compared to the pre-GDL period decreased by 31.3% among those in crashes with one or more drivers ages 16 to 17 years and by 18.7% among those in crashes with one or more drivers ages 18 to 20 years. Among occupants involved in all motor vehicle

crashes in Ohio regardless of driver age, the proportion of occupants involved in crashes with one or more drivers ages 16 to 17 years decreased from 9.2% in the pre-GDL period to 7.3% in the post-GDL period, and for crashes with one or more drivers ages 18 to 20 years, the decrease was from 15.3% in the pre-GDL period to 14.4% in the post-GDL period.

Crashes involving one or more drivers ages 16 to 17 years

In the pre-GDL period, more than one-half (51.3%; 114,355) of all occupants in crashes involving one or more drivers ages 16 to 17 years were male. This percentage decreased slightly in the post-GDL period to 50.9% (77,883). The majority of occupants in these crashes were between the ages of 15 and 17 years in both the pre-GDL (52.6%; 117,337) and post-GDL (51.9%; 79,459) periods. The percentage of adults age 26 years or older increased slightly, from 26.8% (59,802) of occupants in the pre-GDL period to 27.6% (42,227) in the post-GDL period. Mean occupant age increased slightly from 18.6 years in the pre-GDL period to 19.3 years in the post-GDL period. Safety restraint use among vehicle occupants also increased slightly during the study period (pre-GDL: 94.3% vs. post-GDL: 94.9%). The distribution of crash collision types remained relatively steady between the pre-GDL and post-GDL periods, with a slight increase in the percentage of rear-end collisions (pre-GDL: 40.2% vs. post-GDL: 41.6%) and corresponding decreases in the percentages of head-on collisions (pre-GDL: 2.9% vs. post-GDL: 2.6%) and other collision types (pre-GDL: 50.3% vs. post-GDL: 49.1%). In both the pre-GDL and post-GDL period, nearly one-third of crashes occurred between 3:00pm and 5:59pm (pre-GDL: 32.5% vs. post-GDL: 32.7%). Between the pre-

GDL and post-GDL periods, decreases in the percentages of crashes occurring between 6:00pm and 11:59pm (pre-GDL: 27.6% vs. post-GDL: 26.3%) and between 12:00am and 5:59am (pre-GDL: 2.9% vs. post-GDL: 2.4%) were noted, with corresponding increases in the percentages of crashes occurring between 6:00am and 8:59am (pre-GDL: 10.8% vs. post-GDL: 11.9%) and between 9:00am and 3:00pm (pre-GDL: 26.1% vs. post-GDL: 26.7%). The percentage of crashes occurring during the social weekend decreased slightly from 27.7% to 27.0% between the pre-GDL and post-GDL periods. The incidence of speeding decreased from 8.1% of crashes in the pre-GDL period to 6.7% of crashes in the post-GDL period. Alcohol involvement remained relatively steady from the pre-GDL to the post-GDL period (pre-GDL: 0.9% vs. post-GDL: 0.8%).

The proportion of drivers ages 16 to 17 years carrying two or more youth passengers age 25 years or younger by time of day and GDL period is displayed in **Figure 1**. Decreases in the proportions of drivers carrying youth passengers were noted at all crash times between the pre-GDL and post-GDL periods, with the largest decrease observed in the proportion of drivers carrying two or more youth passengers in crashes occurring between 6:00pm and 11:59pm (pre-GDL: 13.4% vs. post-GDL: 10.8%).

Crashes involving one or more drivers ages 18 to 20 years

More than one-half (53.5%; 198,070) of occupants in crashes involving one or more drivers ages 18 to 20 years in the pre-GDL period were male. This percentage decreased slightly to 52.4% (157,541) in the post-GDL period ($p < 0.001$). Nearly one-

half of occupants in these crashes were ages 18 to 20 years, and this remained steady between the pre-GDL (48.4%; 179,017) and post-GDL (48.7%; 146,553) periods. A slight decrease was observed in the percentage of occupants ages 15 to 17 years in the post-GDL period (7.3%; 21,991) when compared with the pre-GDL period (8.1%; 29,986). In addition, there was a small increase in the percentage of occupants age 26 years or older between the pre-GDL period (29.6%; 109,459) and the post-GDL period (30.2%; 90,727). Mean occupant age remained steady over the entire study period (pre-GDL: 19.4 years vs. post-GDL: 19.6 years). Safety restraint use among occupants increased from 94.5% in the pre-GDL period to 95.3% in the post-GDL period ($p < 0.001$). More than three-fourths of occupants were involved in crashes occurring in urban areas, with a slight increase noted between the pre-GDL (82.1%; 303,866) and post-GDL (83.3%; 250,596) periods ($p < 0.001$). More than one-half of crashes occurred between 9:00am and 5:59pm, with a slight increase observed between the pre-GDL (59.1%; 218,381) and post-GDL (59.9%; 180,250) periods. The percentage of crashes occurring during late night (12:00am to 5:59am) and early morning (6:00am to 8:59am) hours decreased modestly between the pre-GDL (5.9% and 8.6%, respectively) and post-GDL (5.5% and 8.3%, respectively) periods. Modest decreases were noted when comparing the pre-GDL and post-GDL periods for percentages of occupants in crashes involving speeding (pre-GDL: 8.4% vs. post-GDL: 7.1%) and alcohol (pre-GDL: 2.2% vs. post-GDL: 1.9%).

Injury and hospital resource utilization

Injury and hospitalization characteristics among occupants injured in motor vehicle crashes involving one or more drivers ages 16 to 20 years are displayed in **Table 5**. Within the pre-GDL period, more than one-fifth (20.5%; 45,676) of occupants in crashes with drivers ages 16 to 17 years were injured and 0.1% (256) were killed. Within the post-GDL period, the percentage of occupants injured was slightly lower (18.7%) and the percentage fatally injured remained steady (0.1%). Compared with the number of occupants injured in the pre-GDL period, the number of occupants injured in the post-GDL period decreased by 37.3% to 28,657. A decrease by almost one-third (32.8%; to 172) was observed among occupants fatally injured in the post-GDL period compared with the pre-GDL period.

During the pre-GDL period, more than one-fifth (21.1%; 78,005) of occupants in crashes with drivers ages 18 to 20 years were injured and 0.2% (556) were killed. In the post-GDL period, 19.7% of involved occupants were injured (19.7%) and 0.1% were killed (0.1%). Compared with the pre-GDL period, the number of occupants injured in the post-GDL period decreased by 23.9% (to 59,385) and the number of occupants fatally injured decreased by 35.2% (to 360).

Among those injured in crashes with one or more drivers ages 16 to 17 years, more than three-fifths of occupants were able to be linked to a hospital record (pre-GDL: 64.5% vs. post-GDL: 61.7%). In the pre-GDL period, 3.9% (1,806) of injured occupants with a linked hospital record were admitted for treatment as inpatients with the remainder being treated in the ED. Comparatively, in the post-GDL period, 2.4% (704) of injured occupants with a linked hospital record were admitted for treatment as inpatients. The number of injured occupants treated as inpatients and in the ED

decreased by 61.0% and 38.6%, respectively, between the pre-GDL and post-GDL periods.

In the pre-GDL period, the vast majority (91.2%; 1,646) of injured occupants in crashes with one or more drivers ages 16 to 17 years had an ISS ≤ 15 , indicating mild injuries. In the post-GDL period, the number of injured occupants with mild injuries decreased by 66.6% to 550. Mild injuries with an ISS ≤ 15 accounted for 78.1% of all injuries in the post-GDL period. The number of those with an ISS of 16-24 remained steady between the pre-GDL (96) and post-GDL periods (95); the percentage of all injuries with an ISS of 16-24 increased from 5.3% in the pre-GDL period to 13.5% in the post-GDL period. The number of injured occupants with an ISS ≥ 25 decreased slightly between the pre-GDL (64) and post-GDL periods (60), while the percentage of all injured occupants with an ISS ≥ 25 increased from 3.5% to 8.5%. Both the number and percentage of injured occupants admitted to the ICU (pre-GDL: 106 [5.9%] vs. post-GDL: 115 [16.4%]; $X^2=11.81$, $p<0.001$) and requiring mechanical ventilation (pre-GDL: 51 [2.8%] vs. post-GDL: 73 [10.4%]; $X^2=17.36$, $p<0.001$) were significantly higher in the post-GDL period compared with the pre-GDL period.

Among those injured in crashes with one or more drivers ages 18 to 20 years, more than three-fifths of occupants were able to be linked to a hospital record (pre-GDL: 62.1% vs. post-GDL: 61.8%). In the pre-GDL period, 4.1% (3,220) of injured occupants with a linked hospital record were admitted for treatment as inpatients with the remainder being treated in the ED. Comparatively, in the post-GDL period, 2.5% (1,469) of injured occupants with a linked hospital record were admitted for treatment as inpatients.

As was observed in the 16 to 17 year age group, there was a decrease of 61.3% in the number of injured occupants with ISS ≤ 15 between the pre-GDL (2,914; 90.5% of all injuries) and post-GDL (1,127; 76.7% of all injuries) periods in crashes with one or more drivers ages 18 to 20 years. The number of those with an ISS of 16-24 increased from 186 (5.8% of all injuries) in the pre-GDL period to 208 (14.1% of all injuries), and the number of those with an ISS ≥ 25 increased from 120 (3.7% of all injuries) in the pre-GDL period to 134 (9.2% of all injuries) in the post-GDL period. In addition, both the number and percentage of injured occupants admitted to the ICU (pre-GDL: 166 [5.1%] vs. post-GDL: 201 [13.7%]; $X^2=14.67$, $p<0.001$) and requiring mechanical ventilation (pre-GDL: 104 [3.2%] vs. post-GDL: 137 [9.3%]; $X^2=14.02$, $p<0.001$) were significantly higher in the post-GDL period compared with the pre-GDL period.

Length of hospital stay

Information on hospital resource utilization among injured occupants is displayed in **Table 6**. During the pre-GDL period, vehicle occupants injured in crashes involving one or more drivers ages 16 to 17 years spent 8,750 days, while occupants injured in crashes involving one or more drivers ages 18 to 20 years spent 16,178 days in the hospital. These totals decreased by 63.2% (3,216) and 55.5% (7,195), respectively, in the post-GDL period. Mean and median LOS decreased slightly among occupants in both driver combined age groups from the pre-GDL to the post-GDL periods. Among occupants injured in crashes involving one or more drivers ages 16 to 17 years, mean (median) LOS went from 4.85 (3.33) days in the pre-GDL period to 4.57 (2.95) days in the post-GDL period. Among occupants injured in crashes involving one or more drivers

ages 18 to 20 years, mean (median) LOS decreased from 5.02 (3.40) days in the pre-GDL period to 4.90 (3.13) days in the post-GDL period.

Among occupants injured in crashes with one or more drivers ages 16 to 17 years, mean (median) LOS among males (4.97 [3.33] days) was slightly higher than among females (4.71 [3.33] days) in the pre-GDL period; however, in the post-GDL period, mean (median) LOS among males decreased to 4.44 (2.95) days while mean (median) LOS among females remained steady at 4.71 (2.96) days. No sizable difference in mean (median) LOS was noted in the pre-GDL period when comparing occupants involved in crashes with speeding ≥ 10 mph over the limit (4.84 [3.25] days) with occupants involved in non-speeding crashes (4.85 [3.33] days). However, in the post-GDL period, mean (median) LOS among occupants in speeding crashes increased to 6.00 (3.38) days, while mean (median) LOS among non-speeding occupants decreased to 4.45 (2.92) days. In the pre-GDL period, mean and median LOS tended to increase as the number of young passengers increased, with a mean (median) LOS of 4.71 (3.28) days noted for drivers with no young passengers, 5.00 (3.39) days for occupants with ≥ 1 young passenger, and 5.27 (3.44) days for occupants with ≥ 2 young passengers. However, decreases in mean and median LOS were noted for each of the three young passenger groups in the post-GDL period, erasing the observed effect of the number of young passengers on mean and median LOS observed in the pre-GDL period.

Among occupants injured in crashes with one or more drivers age 18 to 20 years, mean (median) LOS among males was higher in both the pre-GDL (5.17 [3.38] days) and post-GDL periods (5.09 [3.17] days) compared with females (4.86 [3.42] and 4.65

[3.07] days, respectively). Mean (median) LOS was higher among occupants injured in speeding crashes (6.07 [3.64] days) compared with occupants injured in non-speeding crashes (4.95 [3.38] days) in the pre-GDL period, and despite decreases in mean and median LOS, the trend persisted in the post-GDL period. No trend in mean or median LOS according to the number of young passengers was observed among occupants injured in crashes with one or more drivers ages 18 to 20 years in either the pre-GDL or post-GDL period. Mean (median) LOS was lower in the post-GDL period among occupants in vehicles with no young passengers (4.97 [3.20] days) and with ≥ 1 young passenger (4.78 [3.00] days) compared with the pre-GDL period (5.08 [3.45] days and 4.93 [3.31] days, respectively). A slight increase in mean LOS was observed among occupants in vehicles with ≥ 2 young passengers in the post-GDL period (5.21 days) compared with the pre-GDL period (5.12 days). However, median LOS in this group decreased from 3.39 days in the pre-GDL period to 3.20 days in the post-GDL period.

Hospital charges

During the pre-GDL period, occupants injured in crashes involving one or more drivers ages 16 to 17 years accrued more than \$66.0 million in inpatient hospital charges, while injured occupants in crashes involving one or more drivers ages 18 to 20 years accrued more than \$133.4 million in inpatient hospital charges. These totals decreased by 44.8% (to \$36.4 million) and 39.5% (to \$80.7 million), respectively, in the post-GDL period. Despite decreases in LOS, mean and median hospital charges increased among occupants in both driver combined age groups from the pre-GDL to the post-GDL period. Mean (median) hospital charges increased by 41.6% among

occupants involved in crashes with one or more drivers ages 16 to 17 years, from \$36,570 (\$22,731) in the pre-GDL period to \$51,772 (\$30,759) in the post-GDL period. Among injured occupants involved in crashes with one or more drivers ages 18 to 20 years, mean (median) total charges increased by 32.7%, from \$41,423 (\$24,635) to \$54,960 (\$33,016).

In the pre-GDL period, mean (median) hospital charges were higher among male occupants (\$38,716 [\$23,319]) injured in crashes involving one or more drivers ages 16 to 17 years compared with female occupants (\$34,279 [\$22,122]). Mean and median hospital charges increased by 37.8% among males and 45.6% among females in the post-GDL period, with persisting higher charges among males. In the pre-GDL period, mean (median) hospital charges were higher among occupants injured in speeding-related crashes with one or more drivers ages 16 to 17 years (\$47,381 [\$31,164]) compared with occupants in non-speeding-related crashes (\$36,024 [\$22,375]). In the post-GDL period, mean (median) hospital charges increased by 78.3% to \$84,490 (\$49,784) among occupants in speeding-related crashes, while charges among non-speeding occupants increased by 36.6% to \$49,202 (\$29,624). Similar to the trend observed with LOS, mean (median) hospital charges in the pre-GDL period among occupants injured in crashes involving one or more drivers ages 16 to 17 years increased as the number of young passengers increased, ranging from \$35,667 (\$22,700) for drivers with no young passengers to \$41,917 (\$23,547) for occupants with ≥ 2 young passengers. Mean and median hospital charges increased for all passenger groups in the post-GDL period; however, trends by number of young passengers were no longer as evident.

Among occupants in crashes involving one or more drivers ages 18 to 20 years, mean and median hospital charges were higher among male occupants in both the pre-GDL and post-GDL periods. From the pre-GDL to the post-GDL period, mean hospital charges increased by 29.5% among male occupants and 34.4% among female occupants. Mean (median) hospital charges among occupants involved in speeding-related crashes in the pre-GDL period were nearly 2.5 times higher (\$90,776 [\$36,581]) than among occupants in non-speeding-related crashes (\$38,122 [\$23,993]). In the post-GDL period, mean (median) hospital charges among speeding occupants decreased by 25.4% to \$67,672 (\$41,989) compared with the pre-GDL period. However, mean (median) hospital charges among non-speeding occupants increased by 41.0% to \$53,739 (\$32,258) in the post-GDL period. As was observed for LOS, mean and median hospital charges differed according the number of young passengers; however, no linear trend was evident. Mean hospital charges increased by 28.4% to 48.1% from the pre-GDL to the post-GDL periods in all three young passenger groups.

Crash, injury and fatality rates among occupants

Table 7 reports combined rates per 100,000 persons of crash involvement, injuries, and fatalities involving occupants ages 15 to 20 years by GDL period. Post-GDL crash involvement, injury and fatality rates were consistently lower than pre-GDL rates for both occupants ages 15 to 17 years and 18 to 20 years. The largest declines in post-GDL rates were noted for fatality rates, with decreases of 47.3% and 35.3% among occupants ages 15 to 17 years and 18 to 20 years, respectively. Despite overall decreases in rates between the pre- and post-GDL period, occupants ages 18 to 20

years maintained consistently higher crash involvement, injury, and fatality rates in the post-GDL period compared with occupants ages 15 to 17 years. Injury rates among occupants ages 15 to 17 years decreased from 1810.1 per 100,000 persons in the pre-GDL period to 1143.2 per 100,000 following GDL implementation. Fatality rates among occupants ages 15 to 17 years declined from 12.9 per 100,000 persons prior to GDL implementation to 6.8 per 100,000 post-GDL. Among occupants ages 18 to 20 years, injury rates declined from 2649.1 per 100,000 to 1920.2 per 100,000 and fatality rates declined from 20.4 per 100,000 to 13.2 per 100,000 from the pre-GDL to post-GDL periods.

Table 8 reports adjusted rate ratios comparing crash involvement, injury, and fatality rates post-GDL with rates during the pre-GDL period. In adjusted models with occupants in vehicles with drivers ages 16 to 20 years combined, the post-GDL period was statistically associated with lower crash involvement rates for occupants age 15 years (RR=0.94 [95% CI=0.90-0.97]), age 16 years (RR=0.93 [95% CI=0.91-0.94]), age 17 years (RR=0.92 [95% CI=0.90-0.93]), and age 18 years (RR=0.95 [95% CI=0.94-0.96]), and for occupants age 15 to 17 years combined (RR=0.93 [95% CI=0.92-0.94]). The crash involvement rate was statistically higher for the post-GDL period than for the pre-GDL period for occupants age 19 years (RR=1.06 [95% CI=1.04-1.07]), age 20 years (RR=1.07 [95% CI=1.05-1.09]), and for occupants ages 18 to 20 years combined (RR=1.02 [95% CI=1.01-1.03]). The post-GDL period was statistically associated with lower injury rates for occupants age 16 years (RR=0.88 [95% CI=0.80-0.97]) and age 18 years (RR=0.89 [95% CI=0.83-0.96]).

In models stratified by driver age group, the pattern of results was similar with some exceptions. Crash involvement rates for occupants in crashes with one or more drivers ages 16 to 17 years were statistically lower for the post-GDL period for occupants age 19 years (RR=0.86 [95% CI=0.81-0.91]) and occupants ages 18 to 20 years combined (RR=0.83 [95% CI=0.81-0.86]). In addition, injury rates for occupants age 19 years (RR=0.72 [95% CI=0.54-0.97]) and occupants ages 18 to 20 years combined (RR=0.75 [95% CI=0.64-0.88]) were statistically lower for the post-GDL period. Crash involvement rates among occupants in crashes with one or more drivers ages 18 to 20 years were statistically higher for the post-GDL period than for the pre-GDL period for occupants age 19 years (RR=1.06 [95% CI=1.04-1.08]), age 20 years (RR=1.07 [95% CI=1.05-1.09]), and ages 18 to 20 years combined (RR=1.02 [95% CI=1.01-1.03]). Fatality rate ratios for age-specific and age-combined occupants were not statistically different from the null for the post-GDL period.

Multivariate logistic regression

Adjusted ORs, with 95% confidence intervals and associated p-values for the association of the post-GDL period with medical outcomes are presented in **Table 9**. After controlling for other covariates, the post-GDL period was associated with lower odds of injury and inpatient admission for occupants of both drivers ages 16 to 17 years and ages 18 to 20 years. The post-GDL period was univariately associated with lower odds of occupant fatality among occupants in crashes with one or more drivers age 18 to 20 years, but this association did not persist in multivariate models. In addition, the post-GDL period was associated with higher odds of admission to the ICU and requiring

mechanical ventilation for occupants of both drivers ages 16 to 17 years and drivers ages 18 to 20 years.

Adjusted ORs from multivariate analyses of injury and inpatient admission among occupants in crashes with one or more drivers ages 16 to 17 years, stratified by GDL period, are reported in **Table 10**. Among occupants in crashes with one or more drivers ages 16 to 17 years, female gender, older age (>25 years), front seat position, no restraint use, presence of impaired driver, frontal collision type, rural crash location, summer crash time, late night or early morning crash time, presence of speeding ≥ 10 mph over the limit, and presence of passengers were independently associated with increased occupant injury during the pre-GDL period as well as the post-GDL period. Factors associated with increased occupant inpatient admission in the pre-GDL period included female gender, older age (>25 years), front seat position, no restraint use, male gender of driver, presence of impaired driver, frontal collision type, urban crash location, summer crash time, and presence of speeding ≥ 10 mph over the limit. The association of increased occupant inpatient admission with older age (>25 years), front seat position, no restraint use, presence of impaired driver, urban crash location, frontal collision type, and presence of speeding ≥ 10 mph over the limit persisted in the post-GDL period, along with non-adverse road conditions and late night/early morning crash time.

Adjusted ORs from multivariate analyses among occupants in crashes with one or more drivers ages 18 to 20 years, stratified by GDL period, are reported in **Table 11**. Among occupants in crashes with one or more drivers age 18 to 20 years, female gender, older age (>25 years), front seat position, no restraint use, presence of impaired

driver, rural crash location, frontal collision type, summer crash time, late night or early morning crash time, presence of speeding ≥ 10 mph over the limit, and presence of passengers were independently associated with increased occupant injury during the pre-GDL period. Each of these associations persisted in the post-GDL period. Factors associated with increased occupant inpatient admission in the pre-GDL period included female gender, older age (>25 years), front seat position, no restraint use, passenger status, presence of impaired driver, urban crash location, and frontal collision type. In the post-GDL period, the association of female gender, older age (>25 years), front seat position, no restraint use, passenger status, presence of impaired driver, urban crash location, and frontal collision type with increased occupant inpatient admission persisted. In addition, being an occupant of an “other” vehicle (non-car, van/mini-van, pickup, SUV), male gender of driver, non-adverse weather conditions, late night/early morning crash time and presence of speeding ≥ 10 mph over the limit were independently associated with increased occupant inpatient admission in the post-GDL period among occupants in crashes with one or more drivers ages 18 to 20 years.

DISCUSSION

The results of the current study confirm that implementation of stricter GDL restrictions in Ohio that included nighttime driving and passenger limitations were associated with substantial decreases in the incidence of crashes, injury crashes and fatal crashes among young teen drivers and their occupants. This agrees with previous studies.^{12,19,37} In adjusted analyses, we found the post GDL-period to be significantly associated with decreases in overall crash involvement, injury crash involvement and

fatal crash involvement among drivers and their occupants ages 16 to 17 years. In addition, our study noted statistically significant decreases in the number of teen passengers and the incidence of nighttime driving, indicating that the 2007 GDL law affected the driving patterns of younger teens.

Despite widespread consensus on the beneficial effects of GDL on crash involvement among younger teen drivers and their occupants, the effects on older teen and young adult drivers ages 18 to 20 years is much less clear.¹⁶ Several studies have reported increases in fatal crash rates among drivers age 18 years,^{19,38} while others have found no such deleterious effect,^{11,39} and still others have found no relationship between GDL and the crash rates of drivers ages 18 and 19 years.⁴⁰ Our study found the post-GDL period to be associated with significant decreases in fatal crash rates among drivers and their occupants ages 19 years, 20 years, and 18 to 20 years combined. Fatal crashes represent an atypical subset of all crashes and may not be representative of total crash risk. However, our study did find the post-GDL period to be significantly associated with increases in overall crash involvement for both drivers and occupants ages 19 years, 20 years and 18 to 20 years combined.

Our study noted a higher incidence of crash-related injuries with moderate to severe ISS among occupants of both younger and older teen drivers during the post-GDL period compared with the pre-GDL period. In addition, higher odds of ICU admission and mechanical ventilation were noted in the post-GDL period for occupants of both younger and older teen drivers. Several factors may be at work that help explain these observed relationships. GDL is effective at reducing exposure, thereby reducing overall crash risk. However, the protective stages inherent in GDL restrictions, such as

nighttime driving and driving with passengers, may result in a lack of experience in risky situations.⁴¹ Alternately, although GDL is effective at reducing exposure, it is not designed to address high-risk behaviors, such as speeding and driving while impaired, which are typically associated with more serious injuries.^{42,43} Despite broad countermeasures, such as GDL, that have been effective at reducing overall teen crash rates, young drivers continue to have higher crash, injury and fatality rates than older drivers, suggesting that interventions targeting subgroups of novice drivers may be required. Road safety literature has identified the concept of a “problem young driver” in which a subsample of young drivers, rather than the young driver population as a whole, presents the greatest safety risk through this subgroup’s propensity for engaging in risky driving behaviors.^{44,45} Some research indicates male gender and psychological and physiological factors, such as sensation-seeking propensity, psychological distress, including anxiety and depression, and lower cortisol response, to be associated with riskier driving behavior and higher crash rates;⁴⁶⁻⁴⁸ however, there currently exists no definitive criteria for identifying the “problem young driver.”⁴⁴ More research to determine indicators and specific characteristics may be helpful in devising targeted interventions for the subpopulation at highest risk.

Prior studies noting increases in crash rates among teen drivers ages 18 years or older have speculated that the introduction of GDL laws resulted in many teens delaying licensure until age 18 years, when the restrictions of GDL would no longer apply. It was surmised that the influx of novice drivers inexperienced in risky driving situations was to blame for the increase in crashes among drivers ages 18 to 19 years.¹⁹ Recent surveys of teen drivers have, in fact, found that delay in licensure is widespread, with one study

reporting only 54% of teen drivers having obtained a license before age 18 years.^{49,50} There was little evidence that GDL is a motivator for delaying licensure; instead, teens reported issues, such as not having a car and the costs associated with driving, as being primary reasons for not obtaining a license. In addition, large social and economic disparities in licensing rates and timing of licensure were uncovered, with teens from households with higher incomes and those who self-identified as non-Hispanic whites reporting higher licensing rates prior to age 18 years.⁵⁰ Further pointing to an economic influence for delays in licensure, an overall decrease of 12% in licensing rates among high school seniors was noted between 1996 and 2010, with two-thirds of the decline occurring during 2006-2010, coinciding with the economic recession. Additionally, the proportion of high school seniors who reported not driving during an average week increased during that same 15-year period, with essentially all of the increase occurring during 2006-2009.⁴⁹ Regardless of the reasons for delay, it is evident that the population of older novice drivers continues to grow.

Spurred by the growth in the number of older novice drivers, the issue of whether GDL policies should apply to novice drivers older than age 18 years has recently received more attention in both the policy-making and research communities. Similar to our finding of increased crash rates following GDL among drivers ages 19 to 20 years in Ohio, an increase in possible “injury/property damage only” crashes among drivers age 18 years was noted in Michigan, where like Ohio, GDL restrictions apply only to novice drivers younger than age 18 years.⁵¹ In contrast, decreases in crash rates among older teens age 18 years have been observed in both Maryland and New Jersey, the only two states where GDL restrictions apply to novice drivers older than

age 18 years.^{51,52} Additionally, no adverse effects on crash rates among drivers age 19 years were noted in New Jersey.⁵² In other countries with GDL polices, such as Canada, Australia, and New Zealand, GDL restrictions typically apply to novice drivers of any age based on evidence that the crash risk of older novice drivers, while lower than that of younger novice drivers, is higher than that of same-age experienced drivers.⁵³⁻⁵⁵ In Victoria, Australia, where drivers are not eligible for a probationary license until age 18 years, a recent evaluation has noted substantial reductions in injury crashes during the first year of probationary licensure among drivers ages 18 to 20 years.⁵⁶ The issue of whether or not to include older novice drivers in GDL restrictions remains hotly contested, although two more states are looking to move in that direction. Connecticut recently added a 90-day mandatory learner period for novice drivers age 18 years or older, and in California, a bill has been introduced to extend the state's GDL restrictions to all new drivers up to age 20 years.⁵⁷ Additional monitoring and research is needed; however, our study's findings support extending GDL restrictions to older novice drivers as a promising strategy for bringing about crash reductions among drivers ages 18 to 20 years.

Study Limitations

There were some limitations to this research investigation. The crash database includes uninjured individuals who were not expected to link to a hospital record; however, it is likely there were some injured individuals who received hospital care for whom our probabilistic linkage techniques were unable to link their crash and hospital records. Simulated data linkages using parameters that mimic those of the Ohio

databases have indicated that we are able to detect 83% of the true links. Further, we were unable to ascertain injury status or medical outcome of individuals who sought care at an urgent care center or physician office, resulting in underreporting of injury crashes. Additionally, for those individuals who did not link to a hospital record, we relied on police officers' judgment of medical injuries at the crash scene, which has been shown to be problematic.^{58,59} Hospital charges in this study represent billed hospital charges, rather than hospital costs, and do not include other hospital-related charges, such as physician fees. Thus, the financial information presented likely underestimates the true economic impact of these injuries. Additionally, our metropolitan area variable would be more precise if obtained directly from the police report; however, this information is not available in Ohio, and therefore, derived estimates were made based on the county in which the crash occurred.

CONCLUSIONS

Unlike previous studies evaluating GDL laws, this study used linked data to evaluate the outcomes of all occupants in crashes involving drivers ages 16 to 20 years. In addition, analyses of non-fatal injuries and hospital resource utilization for all occupants were conducted to provide a better understanding of the true public health burden of teen driver-related motor vehicle crashes in Ohio. The results of this study support extending GDL restrictions to older novice drivers as a promising strategy for bringing about crash reductions among drivers ages 18 to 20 years.

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Table 1. Graduated driver licensing law in Ohio.

| Graduated Driver Licensing Law | Minimum Age | Provisions |
|---------------------------------------|--------------------|--|
| Temporary permit | 15 ½ | <ul style="list-style-type: none"> • Valid for 1 year • Must complete driver knowledge test • Age 15 ½ -16 years must be accompanied by eligible adult seated in the front passenger seat when driving^a • Age ≥16 years must be accompanied by a licensed operator age ≥21 years • Age <18 years prohibited from driving between midnight and 6 a.m., unless accompanied by a parent, guardian or legal custodian who holds a valid license |
| Probationary license | 16 | <ul style="list-style-type: none"> • Valid until age 18 years at which time license becomes full driver license • Must have completed driver training certification requirement^b • Must have held temporary permit for ≥6 months • Must complete a state driving and maneuverability test • Age 16 years prohibited from driving between midnight and 6 a.m., unless accompanied by a parent or guardian^c • Age 17 years prohibited from driving between 1 a.m. and 5 a.m., unless accompanied by a parent or guardian^c • Age 16 years prohibited from driving with >1 non-family member in vehicle, unless accompanied by a parent, guardian or legal custodian • May be subject to additional restrictions if commits a moving violation with first 6 months |
| Full license | 18 | <ul style="list-style-type: none"> • No restrictions • If first application for licensure, must complete driver knowledge test and state driving and maneuverability test |

^aEligible adult defined as a parent, guardian, legal custodian, licensed driver ≥21 years of age acting *in loco parentis*, or licensed driving instructor.

^bConsists of 50 hours of driving with a parent/guardian, including 10 hours of nighttime driving, and a driver education requirement of 24 hours of classroom instruction and 8 hours of driving instruction.

^cExceptions apply for an emergency situation, driving to or from a school activity, or driving to or from work.

Table 2. Unadjusted crash, injury crash and fatal crash rates per 100,000 population for drivers ages 16 to 20 years by GDL period, Ohio.

| | Pre-GDL (2004-2006) | Post-GDL (2008-2010) | % Change in Rates |
|----------------------------|--------------------------------|---------------------------------|--------------------------|
| Drivers age 16 to 17 years | | | |
| Crash rate | 8238.1 | 5743.2 | -30.3 |
| Injury crash rate | 2159.0 | 1438.7 | -33.4 |
| Fatal crash rate | 16.4 | 10.6 | -35.4 |
| Drivers age 18 to 20 years | | | |
| Crash rate | 10269.8 | 8010.8 | -22.0 |
| Injury crash rate | 2766.7 | 2080.3 | -24.8 |
| Fatal crash rate | 28.6 | 17.2 | -39.9 |
| Drivers age 16 years | | | |
| Crash rate | 6022.2 | 3944.8 | -34.5 |
| Injury crash rate | 1561.6 | 969.6 | -37.9 |
| Fatal crash rate | 12.1 | 8.8 | -27.3 |
| Drivers age 17 years | | | |
| Crash rate | 10494.2 | 7505.5 | -28.5 |
| Injury crash rate | 2767.3 | 1898.3 | -31.4 |
| Fatal crash rate | 20.7 | 12.5 | -39.6 |
| Drivers age 18 years | | | |
| Crash rate | 12326.0 | 9363.4 | -24.0 |
| Injury crash rate | 3289.9 | 2400.7 | -27.0 |
| Fatal crash rate | 31.9 | 20.9 | -34.5 |
| Drivers age 19 years | | | |
| Crash rate | 11981.2 | 9433.1 | -21.3 |
| Injury crash rate | 3239.3 | 2464.6 | -23.9 |
| Fatal crash rate | 35.4 | 19.9 | -43.8 |
| Drivers age 20 years | | | |
| Crash rate | 6356.9 | 5109.8 | -19.6 |
| Injury crash rate | 1732.7 | 1343.9 | -22.4 |
| Fatal crash rate | 18.2 | 10.5 | -42.3 |

Note: GDL = graduated driver licensing

Table 3. Adjusted rate ratios for post-GDL period compared to pre-GDL period for drivers ages 16 to 20 years, Ohio.

| Driver Age Group | Adjusted RR for overall crash involvement (95% CI)^a | Adjusted RR for injury crash involvement (95% CI)^a | Adjusted RR for fatal crash involvement (95% CI)^a |
|-------------------------|---|--|---|
| Age 16 | 0.94 (0.90-0.98) | 0.86 (0.80-0.93) | 1.22 (0.53-2.77) |
| Age 17 | 0.90 (0.88-0.93) | 0.89 (0.84-0.94) | 0.47 (0.23-0.92) |
| Age 18 | 0.95 (0.92-0.97) | 0.87 (0.83-0.91) | 0.47 (0.26-0.82) |
| Age 19 | 1.04 (1.01-1.07) | 1.02 (0.97-1.07) | 0.74 (0.43-1.27) |
| Age 20 | 1.09 (1.05-1.13) | 1.03 (0.96-1.10) | 0.84 (0.40-1.77) |
| Age 16-17 (combined) | 0.92 (0.90-0.95) | 0.89 (0.85-0.93) | 0.70 (0.41-1.18) |
| Age 18-20 (combined) | 1.02 (1.00-1.03) | 0.96 (0.93-0.99) | 0.65 (0.46-0.93) |

^aAdjusted for annual highway fuel use per capita, average annual gasoline price per gallon, and annual vehicle-miles traveled.

Notes: GDL=graduated driver licensing; RR=rate ratio; CI=confidence interval

Table 4. Population characteristics for occupants in motor vehicle crashes involving one or more drivers ages 16 to 20 years by GDL period, Ohio.

| | Crashes involving 16-17-year-old drivers | | Crashes involving 18-20-year-old drivers | |
|--|--|---------------|--|---------------|
| | Pre-GDL (%) | Post-GDL (%) | Pre-GDL (%) | Post-GDL (%) |
| Total no. occupants ^a | 222846 | 153139 | 369882 | 300839 |
| % of occupants in all crashes ^b | 9.2 | 7.3 | 15.3 | 14.4 |
| Occupant type | | | | |
| Driver | 148805 (66.8) | 102892 (67.2) | 264279 (71.4) | 213352 (70.9) |
| Passenger | 73539 (33.0) | 49914 (32.6) | 104614 (28.3) | 86674 (28.8) |
| Non-occupant | 502 (0.2) | 333 (0.2) | 989 (0.3) | 813 (0.3) |
| Occupant gender | | | | |
| Male | 114355 (51.3) | 77883 (50.9) | 198070 (53.5) | 157541 (52.4) |
| Female | 108491 (48.7) | 75257 (49.1) | 171812 (46.5) | 143298 (47.6) |
| Occupant age (years) | | | | |
| < 15 | 18059 (8.1) | 12477 (8.2) | 24841 (6.7) | 20394 (6.8) |
| 15-17 | 117337 (52.6) | 79459 (51.9) | 29986 (8.1) | 21991 (7.3) |
| 18-20 | 17328 (7.8) | 12070 (7.9) | 179017 (48.4) | 146553 (48.7) |
| 21-25 | 10322 (4.6) | 6906 (4.5) | 26578 (7.2) | 21174 (7.0) |
| ≥ 26 | 59802 (26.8) | 42227 (27.6) | 109459 (29.6) | 90727 (30.2) |
| Mean occupant's age (years) | 18.6 | 19.3 | 19.4 | 19.6 |
| Vehicle type | | | | |
| Car | 150724 (67.6) | 96465 (63.0) | 254033 (68.7) | 197219 (65.6) |
| Van/minivan | 15796 (7.1) | 10507 (6.9) | 25130 (6.8) | 19874 (6.6) |
| Pickup | 22679 (10.2) | 15662 (10.2) | 39034 (10.5) | 29902 (9.9) |
| SUV | 26446 (11.9) | 24807 (16.2) | 39654 (10.7) | 43979 (14.6) |
| Other | 6698 (3.0) | 5365 (3.5) | 11042 (3.0) | 9051 (3.0) |
| Non-motor vehicle ^c | 502 (0.2) | 333 (0.2) | 989 (0.3) | 813 (0.3) |
| Safety restraints used | 209737 (94.3) | 145080 (94.9) | 348525 (94.5) | 285881 (95.3) |
| Crash location | | | | |
| Urban | 175743 (78.9) | 122450 (80.0) | 303866 (82.1) | 250596 (83.3) |
| Rural | 47103 (21.1) | 30690 (20.0) | 66016 (17.9) | 50243 (16.7) |
| Type of collision | | | | |
| Rear-end | 89591 (40.2) | 63695 (41.6) | 146612 (39.6) | 123277 (41.0) |
| Head-on | 6346 (2.9) | 4004 (2.6) | 10813 (2.9) | 8398 (2.8) |
| Side | 14785 (6.6) | 10204 (6.7) | 29253 (7.9) | 23989 (8.0) |
| Other ^d | 112124 (50.3) | 75237 (49.1) | 183203 (49.5) | 145175 (48.3) |
| Crash time | | | | |
| 12:00am – 5:59am | 6571 (2.9) | 3734 (2.4) | 21772 (5.9) | 16576 (5.5) |
| 6:00am – 8:59am | 24099 (10.8) | 18185 (11.9) | 31966 (8.6) | 24963 (8.3) |
| 9:00am – 2:59pm | 58245 (26.1) | 40849 (26.7) | 108312 (29.3) | 89770 (29.8) |

Table 4. Population characteristics for occupants in motor vehicle crashes involving one or more drivers ages 16 to 20 years by GDL period, Ohio (continued).

| | | | | |
|-----------------------------|--------------|--------------|---------------|--------------|
| 3:00pm – 5:59pm | 72348 (32.5) | 50012 (32.7) | 110069 (29.8) | 90480 (30.1) |
| 6:00pm – 11:59pm | 61583 (27.6) | 40360 (26.3) | 97763 (26.4) | 79051 (26.3) |
| Social weekend ^e | 61706 (27.7) | 41287 (27.0) | 102742 (27.8) | 81890 (27.2) |
| Speeding | 18143 (8.1) | 10227 (6.7) | 31015 (8.4) | 21340 (7.1) |
| Alcohol involved | 2082 (0.9) | 1304 (0.8) | 7998 (2.2) | 5607 (1.9) |

^aIncludes drivers and passengers

^bIncludes occupants in all crashes regardless of driver age

^cNon-motor vehicle includes trains, animals with rider or buggy, bicycles, pedestrians, pedalcycles, and skates/skateboards.

^dOther includes vehicular collisions in which the crash vehicles impacted each other at an angle, sideswipe, rear-to-side, rear-to-rear, or end-swipe.

^eSocial weekend is defined as the period beginning at 5:00pm Friday until 4:59pm Sunday.

Notes: GDL = graduated driver licensing; Percentages may not add to 100.0% because of rounding error.

Table 5. Injury and hospitalization characteristics among occupants injured in motor vehicle crashes involving one or more drivers ages 16 to 20 years by GDL period, Ohio.

| | Crashes involving 16-17 year old drivers | | Crashes involving 18-20 year old drivers | |
|--|--|--------------|--|--------------|
| | Pre-GDL (%) | Post-GDL (%) | Pre-GDL (%) | Post-GDL (%) |
| Total no. occupants ^a | 222846 | 153139 | 369882 | 300839 |
| No. injuries | 45676 (20.5) | 28657 (18.7) | 78005 (21.1) | 59385 (19.7) |
| No. killed ^b | 256 (0.1) | 172 (0.1) | 556 (0.2) | 360 (0.1) |
| Hospital level of care | | | | |
| Unlinked | 16215 (35.5) | 10969 (38.3) | 29536 (37.9) | 22704 (38.2) |
| Emergency department | 27655 (60.6) | 16984 (59.3) | 45249 (58.0) | 35212 (59.3) |
| Inpatient | 1806 (3.9) | 704 (2.4) | 3220 (4.1) | 1469 (2.5) |
| Body region injured | | | | |
| Head/neck | 8703 (29.5) | 5320 (30.1) | 13761 (28.4) | 10618 (28.9) |
| Spine/back | 10567 (35.9) | 6725 (38.0) | 18666 (38.5) | 14569 (39.7) |
| Torso | 5048 (17.1) | 3028 (17.1) | 8527 (17.6) | 6449 (17.6) |
| Upper extremity | 7865 (26.7) | 4117 (23.4) | 12427 (25.6) | 8048 (21.9) |
| Lower extremity | 6479 (22.0) | 3512 (19.8) | 10550 (21.8) | 7121 (19.4) |
| Other | 2208 (7.5) | 1463 (8.3) | 3728 (7.7) | 3069 (8.4) |
| Discharge status | | | | |
| Home | 28788 (97.7) | 17424 (98.5) | 47190 (97.4) | 36036 (98.2) |
| Died | 65 (0.2) | 62 (0.4) | 149 (0.3) | 112 (0.3) |
| Rehabilitation | 97 (0.3) | 57 (0.3) | 174 (0.4) | 118 (0.3) |
| Long term care | 403 (1.4) | 96 (0.5) | 714 (1.5) | 210 (0.6) |
| Left against medical advice | 107 (0.4) | 48 (0.3) | 241 (0.5) | 205 (0.6) |
| Injury severity score (ISS) ^c | | | | |
| ≤ 15 (mild) | 1646 (91.2) | 550 (78.1) | 2914 (90.5) | 1127 (76.7) |
| 16-24 (moderate) | 96 (5.3) | 95 (13.5) | 186 (5.8) | 208 (14.1) |
| ≥ 25 (severe) | 64 (3.5) | 60 (8.5) | 120 (3.7) | 134 (9.2) |
| Admitted to ICU ^c | 106 (5.9) | 115 (16.4) | 166 (5.1) | 201 (13.7) |
| Required mechanical ventilation ^c | 51 (2.8) | 73 (10.4) | 104 (3.2) | 137 (9.3) |

^aIncludes drivers and passengers

^bIncludes deaths as determined by police report and/or hospital record.

^cProportions calculated among injured occupants admitted to the hospital as inpatients

Notes: GDL = graduated driver licensing; ISS = injury severity score; Percentages may not add to 100.0% because of rounding error.

Table 6. Length of stay and total charges for inpatient hospitalizations among occupants of motor vehicle crashes involving one or more drivers age 16 to 20 years, by GDL period, Ohio.

| Descriptive Statistics | Mean Length of Stay (days) (median) | | Mean Total Charges (US dollars) (median) | |
|--|-------------------------------------|-------------------------|--|-------------------------|
| | Pre-GDL (2004-2006) | Post-GDL (2008-2010) | Pre-GDL (2004-2006) | Post-GDL (2008-2010) |
| Crashes involving drivers ages 16 to 17 yrs | | | | |
| Driver gender | | | | |
| Male | 4.97 (3.33) | 4.44 (2.95) | 38,716 (23,319) | 53,336 (33,058) |
| Female | 4.71 (3.33) | 4.71 (2.96) | 34,279 (22,122) | 49,916 (28,261) |
| Speeding | | | | |
| ≥10 mph over limit | 4.84 (3.25) | 6.00 (3.38) | 47,381 (31,164) | 84,490 (49,784) |
| No speeding | 4.85 (3.33) | 4.45 (2.92) | 36,024 (22,375) | 49,202 (29,624) |
| No. young passengers ^a | | | | |
| 0 | 4.71 (3.28) | 4.50 (3.05) | 35,667 (22,700) | 50,265 (30,476) |
| ≥1 | 5.00 (3.39) | 4.65 (2.84) | 37,592 (22,767) | 53,775 (31,137) |
| ≥2 | 5.27 (3.44) | 4.57 (2.84) | 41,917 (23,547) | 53,541 (30,314) |
| Overall | | | | |
| Mean (SE) | 4.85 (0.14) | 4.57 (0.26) | 36,570 (1,347) | 51,772 (3,028) |
| Median | 3.33 | 2.95 | 22,731 | 30,759 |
| Range | 1-79 | 1-103 | 952-1,086,415 | 2,531-738,791 |
| Total | 8,750 | 3,216 | 66,034,275 | 36,457,684 |
| Crashes involving drivers ages 18 to 20 yrs | | | | |
| Driver gender | | | | |
| Male | 5.17 (3.38) | 5.09 (3.17) | 46,382 (25,861) | 60,059 (35,637) |
| Female | 4.86 (3.42) | 4.65 (3.07) | 36,053 (23,372) | 48,461 (29,948) |
| Speeding | | | | |
| ≥10 mph over limit | 6.07 (3.64) | 5.32 (3.06) | 90,776 (36,581) | 67,672 (41,989) |
| No speeding | 4.95 (3.38) | 4.86 (3.13) | 38,122 (23,993) | 53,739 (32,258) |
| No. young passengers ^a | | | | |
| 0 | 5.08 (3.45) | 4.97 (3.20) | 43,310 (25,192) | 55,629 (32,740) |
| ≥1 | 4.93 (3.31) | 4.78 (3.00) | 38,371 (23,757) | 53,769 (33,517) |
| ≥2 | | | | |
| Overall | | | | |
| Mean (SE) | 5.02 (0.11) | 4.90 (0.17) | 41,423 (2,338) | 54,960 (2,111) |
| Median | 3.40 | 3.13 | 24,635 | 33,016 |
| Range | 1-87 | 1-84 | 912-8,945,834 | 1,263-851,120 |
| Total | 16,178 | 7,195 | 133,400,633 | 80,751,684 |

^aYoung passengers are defined as non-driving occupants age 25 years or younger.

Notes: GDL = graduated driver licensing; mph = miles per hour; SE = standard error

Table 7. Crash, injury and fatality rates per 100,000 persons for occupants in motor vehicle crashes involving one or more drivers ages 16 to 20 years by GDL period, Ohio.

| | Pre-GDL (2004-2006) | Post-GDL (2008-2010) | % Change |
|--|--------------------------------|---------------------------------|-----------------|
| Number of occupants age 15 to 17 years involved in crashes | 135710 | 93648 | -31.0 |
| Crash involvement rate among occupants age 15 to 17 years | 8946.9 | 6313.0 | -29.4 |
| Number of occupants age 18 to 20 years involved in crashes | 185769 | 151564 | -18.4 |
| Crash involvement rate among occupants age 18 to 20 years | 12926.7 | 10155.3 | -21.4 |
| Number of injuries among occupants age 15 to 17 years | 27456 | 16958 | -38.2 |
| Injury rate among occupants age 15 to 17 years | 1810.1 | 1143.2 | -36.8 |
| Number of injuries among occupants age 18 to 20 years | 38070 | 28659 | -24.7 |
| Injury rate among occupants age 18 to 20 years | 2649.1 | 1920.2 | -27.5 |
| Number of fatalities among occupants age 15 to 17 years | 195 | 101 | -48.2 |
| Fatality rate among occupants age 15 to 17 years | 12.9 | 6.8 | -47.3 |
| Number of fatalities among occupants age 18 to 20 years | 293 | 197 | -32.8 |
| Fatality rate among occupants age 18 to 20 years | 20.4 | 13.2 | -35.3 |

Note: GDL = graduated driver licensing

Table 8. Adjusted rate ratios for post-GDL period compared with pre-GDL period for occupants of motor vehicle crashes, Ohio.

| Occupant Age Group | Adjusted RR for motor vehicle crash involvement (95% CI)^a | Adjusted RR for motor vehicle crash-related injury (95% CI)^a | Adjusted RR for motor vehicle crash-related fatality (95% CI)^a |
|--------------------------------------|---|--|--|
| 16-to 20-year old drivers (combined) | | | |
| Age 15 | 0.94 (0.90-0.97) | 0.95 (0.79-1.14) | 3.57 (0.20-62.96) |
| Age 16 | 0.93 (0.91-0.94) | 0.88 (0.80-0.97) | 1.48 (0.46-4.81) |
| Age 17 | 0.92 (0.90-0.93) | 0.96 (0.89-1.04) | 0.38 (0.14-1.06) |
| Age 18 | 0.95 (0.94-0.96) | 0.89 (0.83-0.96) | 0.66 (0.28-1.52) |
| Age 19 | 1.06 (1.04-1.07) | 1.07 (0.99-1.15) | 0.79 (0.32-1.97) |
| Age 20 | 1.07 (1.05-1.09) | 1.04 (0.94-1.16) | 1.40 (0.36-5.37) |
| Age 15-17 (combined) | 0.93 (0.92-0.94) | 0.94 (0.89-1.00) | 0.80 (0.38-1.68) |
| Age 18-20 (combined) | 1.02 (1.01-1.03) | 0.99 (0.95-1.04) | 0.81 (0.46-1.42) |
| 16-to 17-year old drivers (combined) | | | |
| Age 15 | 0.90 (0.86-0.94) | 0.85 (0.67-1.08) | 1.00 (1.00-1.00) |
| Age 16 | 0.91 (0.89-0.93) | 0.88 (0.79-0.97) | 1.40 (0.39-5.05) |
| Age 17 | 0.89 (0.88-0.90) | 0.95 (0.87-1.03) | 0.36 (0.12-1.08) |
| Age 18 | 0.78 (0.75-0.82) | 0.76 (0.61-0.94) | 0.62 (0.04-10.48) |
| Age 19 | 0.86 (0.81-0.91) | 0.72 (0.54-0.97) | -- |
| Age 20 | 0.93 (0.86-1.00) | 0.74 (0.52-1.05) | -- |
| Age 15-17 (combined) | 0.91 (0.90-0.92) | 0.92 (0.87-0.98) | 0.73 (0.32-1.64) |
| Age 18-20 (combined) | 0.83 (0.81-0.86) | 0.75 (0.64-0.88) | 0.77 (0.09-6.97) |
| 18-to 20-year old drivers (combined) | | | |
| Age 15 | 0.92 (0.87-0.97) | 1.11 (0.84-1.46) | -- |
| Age 16 | 1.04 (1.00-1.09) | 0.81 (0.66-0.99) | 0.90 (0.05-15.29) |
| Age 17 | 1.03 (1.00-1.07) | 1.00 (0.84-1.18) | 0.51 (0.05-5.59) |
| Age 18 | 0.96 (0.94-0.97) | 0.90 (0.83-0.97) | 0.62 (0.26-1.51) |
| Age 19 | 1.06 (1.04-1.08) | 1.08 (1.00-1.16) | 0.80 (0.32-2.03) |
| Age 20 | 1.07 (1.05-1.09) | 1.04 (0.94-1.16) | 1.32 (0.34-5.21) |
| Age 15-17 (combined) | 1.02 (1.00-1.05) | 0.96 (0.85-1.08) | 0.85 (0.16-4.58) |
| Age 18-20 (combined) | 1.02 (1.01-1.03) | 1.00 (0.95-1.05) | 0.79 (0.44-1.41) |

^aAdjusted for annual highway fuel use per capita, average annual gasoline price per gallon, and annual vehicle-miles traveled.

Notes: GDL=graduated driver licensing; RR=rate ratio; CI=confidence interval

Table 9. Multivariate odds ratios for association of post-GDL period (2008-2010) with medical outcomes for occupants in motor vehicle crashes involving one or more drivers ages 16 to 20 years, Ohio.

| Outcome | Crashes involving drivers ages 16 to 17 yrs | | Crashes involving drivers ages 18 to 20 yrs | |
|--------------------------------------|---|-------------------|---|-------------------|
| | Post-GDL | | Post-GDL | |
| | OR ^a (95% CI) | p-value | OR ^a (95% CI) | p-value |
| Injury | 0.92 (0.90-0.94) | <0.0001 | 0.94 (0.93-0.95) | <0.0001 |
| Death | 1.01 (0.82-1.25) | 0.893 | 0.90 (0.78-1.04) | 0.147 |
| Inpatient admission | 0.58 (0.53-0.64) | <0.0001 | 0.57 (0.52-0.62) | <0.0001 |
| ISS ≥ 16 | 1.11 (0.91-1.35) | 0.288 | 1.08 (0.94-1.24) | 0.251 |
| Admission to rehabilitation facility | 0.90 (0.64-1.27) | 0.561 | 0.87 (0.67-1.13) | 0.297 |
| Admission to ICU | 1.71 (1.27-2.30) | 0.0004 | 1.65 (1.33-2.05) | <0.0001 |
| Required mechanical ventilation | 2.23 (1.51-3.30) | <0.0001 | 1.73 (1.32-2.28) | <0.0001 |

^aOdds ratios adjusted for significant (p<0.05) confounders including gender, age, vehicle type, seating position, restraint use, person type, driver gender, driver impairment, location type, collision type, road conditions, weather conditions, light conditions, social weekend, summer months, crash time, speeding, number of young passengers ages ≤ 25 years, and number of adult passengers.
Notes: GDL=graduated driver licensing; OR=adjusted odds ratio; ISS=Injury Severity Score; ICU=intensive care unit

Table 10. Multivariate odds ratios for injury and death for occupants in motor vehicle crashes involving one or more drivers ages 16 to 17 years, by GDL period, Ohio.

| Characteristic | Injury | | | | Inpatient Admission | | | |
|---------------------------------------|---------------------|---------|----------------------|---------|---------------------|---------|----------------------|---------|
| | Pre-GDL (2004-2006) | | Post-GDL (2008-2010) | | Pre-GDL (2004-2006) | | Post-GDL (2008-2010) | |
| | OR | p-value | OR | p-value | OR | p-value | OR | p-value |
| Male | 0.68 | <0.001 | 0.69 | <0.001 | 0.70 | <0.0001 | -- | -- |
| Age <15 | 0.80 | <0.001 | 0.70 | <0.001 | 0.72 | 0.006 | 0.27 | <0.0001 |
| Age 15 to 17 | 0.76 | <0.001 | 0.69 | <0.001 | 0.72 | <0.0001 | 0.57 | <0.0001 |
| Age 18 to 20 | 0.83 | <0.001 | 0.75 | <0.001 | 0.74 | 0.006 | 0.57 | 0.001 |
| Age 21 to 24 | 0.93 | 0.011 | 0.90 | 0.004 | 0.71 | 0.016 | 0.39 | 0.001 |
| Van/minivan | 0.81 | <0.001 | 0.81 | <0.001 | 0.96 | 0.691 | -- | -- |
| Pickup | 0.87 | <0.001 | 0.83 | <0.001 | 0.84 | 0.068 | -- | -- |
| SUV | 0.82 | <0.001 | 0.86 | <0.001 | 0.79 | 0.008 | -- | -- |
| Other vehicle | 0.33 | <0.001 | 0.29 | <0.001 | 0.65 | 0.007 | -- | -- |
| Front seat | 1.37 | <0.001 | 1.23 | <0.001 | 1.30 | 0.003 | 1.45 | 0.034 |
| Restraint used | 0.29 | <0.001 | 0.28 | <0.001 | 0.27 | <0.0001 | 0.15 | <0.0001 |
| Driver | 0.95 | 0.003 | -- | -- | -- | -- | -- | -- |
| Male driver | 0.97 | 0.038 | -- | -- | 1.26 | 0.003 | -- | -- |
| Driver drinking | 1.69 | <0.001 | 2.10 | <0.001 | 1.94 | <0.0001 | 1.90 | 0.002 |
| Urban | 0.85 | <0.001 | 0.81 | <0.001 | 1.17 | 0.013 | 1.43 | 0.003 |
| Front collision | 2.43 | <0.001 | 2.35 | <0.001 | 2.11 | <0.0001 | 3.24 | <0.0001 |
| Rear collision | 0.74 | <0.001 | 0.67 | <0.001 | 0.55 | <0.0001 | 0.30 | <0.0001 |
| Adverse road conditions | -- | -- | 0.90 | <0.001 | -- | -- | 0.65 | 0.0002 |
| Adverse weather conditions | 0.93 | <0.001 | 0.95 | 0.029 | -- | -- | -- | -- |
| Social weekend ^a | -- | -- | -- | -- | -- | -- | -- | -- |
| Summer ^b | 1.12 | <0.001 | 1.13 | <0.001 | 1.32 | <0.0001 | 1.27 | 0.013 |
| Time 12:00am-5:59am | 1.28 | <0.001 | 1.17 | <0.001 | -- | -- | 1.45 | 0.045 |
| Time 6:00am-8:59am | 1.06 | 0.004 | 1.03 | 0.172 | -- | -- | 0.85 | 0.282 |
| Time 3:00pm-5:59pm | 1.00 | 0.933 | 0.97 | 0.106 | -- | -- | 0.93 | 0.468 |
| Time 6:00pm-11:59pm | 1.05 | 0.002 | 1.05 | 0.010 | -- | -- | 0.71 | 0.010 |
| Speeding \geq 10mph over limit | 1.81 | <0.001 | 1.84 | <0.001 | 1.79 | <0.0001 | 2.36 | <0.0001 |
| \geq 1 young passenger ^c | 1.14 | <0.001 | 1.13 | <0.001 | -- | -- | -- | -- |
| \geq 1 adult passenger ^d | 1.14 | <0.001 | 1.16 | <0.001 | -- | -- | -- | -- |

^aSocial weekend is defined as the period beginning at 5:00pm Friday until 4:59pm Sunday.

^bSummer is defined as June, July and August

^cA young passenger is defined as age \leq 25 years.

^dAn adult passenger is defined as age $>$ 25 years.

Notes: GDL=graduated driver licensing; OR=adjusted odds ratio; ISS=Injury Severity Score; Reference categories: age 25 yrs or older, female gender, occupant of car, rear seat position, no safety restraint use, passenger, female driver, non-drinking driver, rural crash location, side or other impact collision, non-adverse road conditions, non-adverse weather conditions, 5:00pm Sunday through 4:59pm Friday, non-Summer (September through May), 9:00am to 2:59pm crash time, $<$ 10mph over speed limit, no young passengers, no adult passengers.

Table 11. Multivariate odds ratios for injury and death for occupants in motor vehicle crashes involving one or more drivers ages 18 to 20 years, by GDL period, Ohio.

| Characteristic | Injury | | | | Inpatient Admission | | | |
|---------------------------------|---------------------|---------|----------------------|---------|---------------------|---------|----------------------|---------|
| | Pre-GDL (2004-2006) | | Post-GDL (2008-2010) | | Pre-GDL (2004-2006) | | Post-GDL (2008-2010) | |
| | OR | p-value | OR | p-value | OR | p-value | OR | p-value |
| Male | 0.66 | <0.001 | 0.68 | <0.001 | 0.78 | <0.0001 | 0.73 | 0.001 |
| Age <15 | 0.82 | <0.001 | 0.72 | <0.001 | 0.64 | <0.0001 | 0.30 | <0.0001 |
| Age 15 to 17 | 0.78 | <0.001 | 0.72 | <0.001 | 0.63 | <0.0001 | 0.52 | <0.0001 |
| Age 18 to 20 | 0.84 | <0.001 | 0.79 | <0.001 | 0.79 | <0.0001 | 0.60 | <0.0001 |
| Age 21 to 24 | 0.92 | <0.001 | 0.88 | <0.001 | 0.78 | 0.003 | 0.63 | 0.0003 |
| Van/minivan | 0.77 | <0.001 | 0.86 | <0.001 | 0.87 | 0.086 | 0.81 | 0.107 |
| Pickup | 0.78 | <0.001 | 0.80 | <0.001 | 0.76 | 0.0003 | 0.61 | <0.0001 |
| SUV | 0.85 | <0.001 | 0.82 | <0.001 | 0.96 | 0.535 | 0.86 | 0.111 |
| Other vehicle | 0.51 | <0.001 | 0.47 | <0.001 | 0.97 | 0.742 | 1.30 | 0.042 |
| Front seat | 1.42 | <0.001 | 1.33 | <0.001 | 1.46 | <0.0001 | 1.68 | <0.0001 |
| Restraint used | 0.29 | <0.001 | 0.27 | <0.001 | 0.26 | <0.0001 | 0.15 | <0.0001 |
| Driver | 0.89 | <0.001 | 0.90 | <0.001 | 0.83 | 0.001 | 0.83 | 0.034 |
| Male driver | 0.97 | 0.023 | 0.95 | <0.001 | -- | -- | 1.27 | 0.007 |
| Driver drinking | 1.83 | <0.001 | 1.87 | <0.001 | 2.18 | <0.0001 | 2.70 | <0.0001 |
| Urban | 0.91 | <0.001 | 0.87 | <0.001 | 1.35 | <0.0001 | 1.24 | 0.012 |
| Front collision | 2.64 | <0.001 | 2.55 | <0.001 | 2.51 | <0.0001 | 3.03 | <0.0001 |
| Rear collision | 0.84 | <0.001 | 0.78 | <0.001 | 0.58 | <0.0001 | 0.35 | <0.0001 |
| Adverse road conditions | 0.95 | <0.001 | 0.95 | 0.002 | -- | -- | -- | -- |
| Adverse weather conditions | -- | -- | 0.92 | <0.001 | -- | -- | 0.66 | <0.0001 |
| Social weekend ^a | -- | -- | -- | -- | -- | -- | -- | -- |
| Summer ^b | 1.09 | <0.001 | 1.10 | <0.001 | -- | -- | -- | -- |
| Time 12:00am-5:59am | 1.08 | <0.001 | 1.13 | <0.001 | -- | -- | 1.39 | 0.002 |
| Time 6:00am-8:59am | 1.06 | <0.001 | 1.01 | 0.432 | -- | -- | 1.02 | 0.891 |
| Time 3:00pm-5:59pm | 0.93 | <0.001 | 0.93 | <0.001 | -- | -- | 1.01 | 0.862 |
| Time 6:00pm-11:59pm | 0.97 | 0.002 | 0.96 | <0.001 | -- | -- | 0.69 | <0.0001 |
| Speeding ≥10mph over limit | 1.81 | <0.001 | 1.85 | <0.001 | -- | -- | 2.38 | <0.0001 |
| ≥1 young passenger ^c | 1.13 | <0.001 | 1.15 | <0.001 | -- | -- | -- | -- |
| ≥1 adult passenger ^d | 1.24 | <0.001 | 1.19 | <0.001 | -- | -- | -- | -- |

^aSocial weekend is defined as the period beginning at 5:00pm Friday until 4:59pm Sunday.

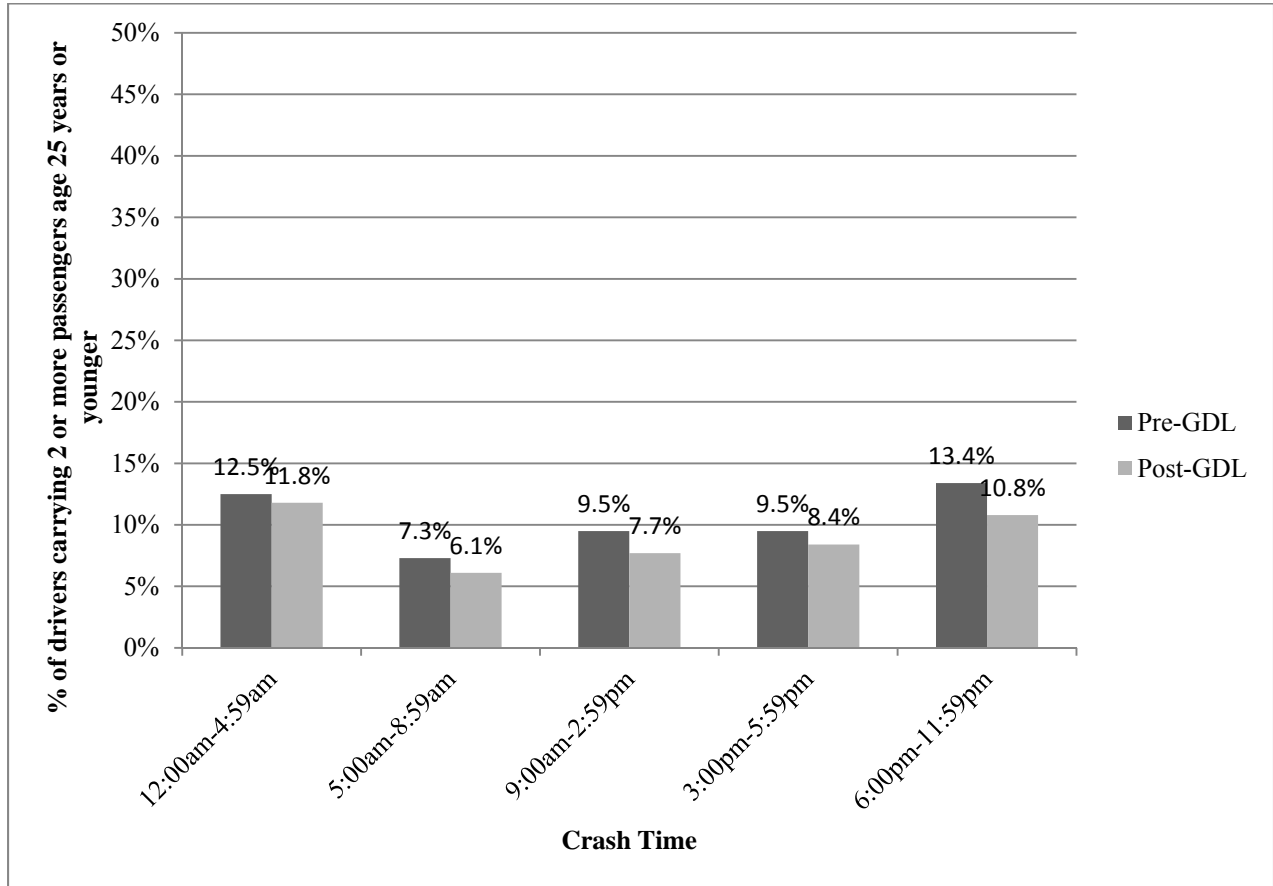
^bSummer is defined as June, July and August

^cA young passenger is defined as age ≤25 years.

^dAn adult passenger is defined as age >25 years.

Notes: GDL=graduated driver licensing; OR=adjusted odds ratio; ISS=Injury Severity Score; Reference categories: age 25 yrs or older, female gender, occupant of car, rear seat position, no safety restraint use, passenger, female driver, non-drinking driver, rural crash location, side or other impact collision, non-adverse road conditions, non-adverse weather conditions, 5:00pm Sunday through 4:59pm Friday, non-Summer (September through May), 9:00am to 2:59pm crash time, <10mph over speed limit, no young passengers, no adult passengers.

Figure 1. Proportion of drivers age 16-17 years carrying two or more passengers age 25 years or younger, by time of day and GDL period, Ohio.



Note: GDL = graduated driver licensing