Published in final edited form as:
Inj Prev. 2013 February ; 19(1): 49–57. doi:10.1136/injuryprev-2012-040474.

Graduated driver licensing and motor vehicle crashes involving teenage drivers: an exploratory age-stratified meta-analysis

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Abstract

Objective—Graduated Driver Licensing (GDL) has been implemented in Australia, Canada, New Zealand, USA and Israel. We conducted an exploratory summary of available data to estimate whether GDL effects varied with age.

Methods—We searched MEDLINE and other sources from 1991–2011. GDL evaluation studies with crashes resulting in injuries or deaths were eligible. They had to provide age-specific incidence rate ratios with CI or information for calculating these quantities. We included studies from individual states or provinces, but excluded national studies. We examined rates based on person-years, not license-years.

Results—Of 1397 papers, 144 were screened by abstract and 47 were reviewed. Twelve studies from 11 US states and one Canadian province were selected for meta-analysis for age 16, eight were selected for age 17, and four for age 18. Adjusted rate ratios were pooled using random effects models. The pooled adjusted rate ratios for the association of GDL presence with crash rates was 0.78 (95% CI 0.72 to 0.84) for age 16 years, 0.94 (95% CI 0.93 to 0.96) for 17 and 1.00 (95% CI 0.95 to 1.04) for 18. The difference between these three rate ratios was statistically significant: $p<0.001$.

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Contributors MZ originated and designed the study, conducted data analysis, and led the writing. PC verified data extraction, provided expertise in meta-analysis, offered suggestions for data analysis, and critically reviewed the manuscript. HC, JHC and GL critically reviewed and substantially revised the manuscript.

Competing interests None.

Provenance and peer review Not commissioned; externally peer reviewed.

Conclusions—GDL policies were associated with a 22% reduction in crash rates among 16-year-old drivers, but only a 6% reduction for 17-year-old drivers. GDL showed no association with crashes among 18-year-old drivers. Because we had few studies to summarise, particularly for older adolescents, our findings should be considered exploratory.

INTRODUCTION

Motor vehicle collisions are a major source of morbidity and mortality around the world, causing about 20–50 million injuries and 1.2 million deaths every year.[1] Motor vehicle crashes are the leading cause of death among people aged 15–29 years worldwide.[12] Young novice drivers have the highest crash rate; per kilometre driven, the crash rate for 16-year-old drivers is approximately four times greater than that for drivers ages 30–59 years in the USA.[3] This excess crash risk is mainly due to inexperience and risky driving behaviours.[4–6] To address this issue, some European countries including Sweden, Norway, France and Belgium have implemented an extended learner permit phase, requiring supervised driving under all conditions for adolescent drivers before they reach 18 years.[7–9] Australia, Canada, New Zealand, the USA and Israel have implemented Graduated Driver Licensing (GDL) laws in some or all states/provinces.[10–15] GDLs in Australia and Canada apply to drivers of all ages. In the USA, New Jersey's GDL system applies to people entering the licensing process who are under 21, and some other states apply some restrictions to people 18 and older. In the USA, GDL regulates licensing and driving behaviours among adolescents younger than 18 years in three phases: the *extended learner phase*, requiring supervised driving under any conditions for 3–12 months; the *intermediate phase*, allowing unsupervised driving under low-risk conditions such as daylight or when carrying less than one young passenger; and the *full licensure phase*, permitting unsupervised driving all the time.

GDL policies could reduce crash rates if they reduced risky driving behaviours among those covered by GDL restrictions. Or they might reduce crash rates by reducing the amount of driving by adolescents. Either of these mechanisms would reduce crash rates for drivers age 16 and 17 years, while rates for those 18 years would be unchanged. One effect of GDL programmes is to delay licensure by increasing the minimum permit and/or intermediate license age, or by placing additional requirements on teenagers such as minimum practice driving hours. Another possibility is that GDL laws may reduce crash rates among those age 16 and 17 years, but crash rates might *increase* among drivers age 18 years because they drive fewer miles and therefore learn fewer driving skills while driving under GDL laws at ages 16 and 17. In states that do not apply GDL to people 18 and older, teenagers might delay licensure until 18 and thereby have higher crash rates at age 18 because they are new drivers. Another possibility is that crash rates are reduced among drivers age 16 and 17 years, and also among drivers age 18 years because teenagers licensed under GDL would have a greater amount of practice and gradual introduction to riskier driving situations and thereby lower crash rates at age 18.

GDL implementation has been reported to reduce involvement in a vehicle crash as a driver by approximately 15–40% for adolescents aged 16 years.[16–20] One reason that studies have found different effects of GDL is because some GDLs have more restrictive provisions than others. In addition, the definition used for a GDL law has varied among studies.[16171920] Few studies have examined 17-year-old and 18-year-old drivers. The potential effect of GDL on teenagers age 18 years is primarily a US issue, as other countries have older licensing ages and most apply GDL to drivers of all ages. A study of US fatal crashes reported similar crash rates among teenagers age 18 years before and after GDL implementation,[17] but another study of fatal US crashes found that GDL was associated with a 10% increase in fatal crash involvements among those age 18.[16] We conducted a systematic review and meta-analysis to estimate age-specific associations between GDL implementation and crash rates.

METHODS

We searched MEDLINE, Transportation Research Information Service, Web of Science, Google Scholar, and internet sites maintained by the Insurance Institute for Highway Safety, the National Highway Traffic Safety Administration, the Centres for Disease Control and Prevention, and the American Automobile Association Foundation for Traffic Safety for studies of GDL polices from January 1991 through December 2011. Our search terms included: (1) GDL; (2) (graduate* or gradual* or delay* or driver or provisional) in combination with (permit* or licen* or restrict* or delay*); (3) (teen* or you* or adolescen*) in combination with (driv*). We used the ‘related citations’ feature to capture additional references for selected articles. We examined the references of articles and reviews.[182122]

Full-text versions of articles or reports were reviewed by the first author (MZ). Data extraction was conducted by the first author (MZ) and verified by the second author (PC). For this study we defined GDL as a new law with a learner phase of at least 3-months plus an intermediate phase that restricts driving at night and/or restricts the number of passengers allowed.[23] To be included in the meta-analysis, a study had to use counts of crashes, injuries or deaths as the outcome. It had to provide age-specific incidence rate ratio estimates with CI or information that allowed us to calculate these quantities. We included studies from individual states or provinces. We excluded national studies because within a given nation they have overlapping time periods and therefore their results are not independent. In addition, national studies overlap the time intervals of most studies from smaller jurisdictions such as states. We examined rates based on person-years, and did not consider rates based on license-years because license data for adolescents is not often or consistently reported by states/ provinces. Some jurisdictions include adolescents in the intermediate phase, while others count only those fully licensed.

Not all studies used the same outcomes. When extracting rate or rate ratio estimates, we first used an estimate based on the count of crashes in which a teenager was involved as a driver and at least one person was injured. Our second choice was a count of injured teenage drivers. Third was a count of crashes with a teenage driver and at least one death. Fourth was a count of fatally injured teenage drivers. We extracted the year of GDL implementation and information about each law. We identified whether the original manuscript adjusted the rate ratio for temporal trends using rate data from drivers age 21 and older, who should not be affected by GDL laws but should be affected by other factors that influence crash rates, such as changes in speed laws, seat belt use or vehicle design.

Our goal was to pool age-specific rate ratios from each study to summarise the association between GDL presence and crash rates. One study (North Carolina)[15] provided an age-specific rate ratio that was not adjusted for other changes in rates over time; an adjusted estimate was not available. The needed rate ratios with CIs were not in the remaining studies. We therefore extracted from each study age-specific counts of outcome events (crashes with an injury or counts of injured drivers) and population estimates before and after GDL passage. These data came from 1–5.5 years of time before GDL passage and 1–6.5 years after passage. We used age categories of 16, 17 and 18 years as well as a category for older drivers if that information was available. We estimated adjusted rate ratios (aRR) for the association of GDL laws with crash rates using Poisson regression, with age-specific person-time as offsets. We adjusted for age group and included interaction terms between GDL presence and adolescent age groups. Except for NC, we adjusted for time as a linear term in all models to account for changes in crash rates over time due to factors other than GDL laws; but the method used depended upon the available data. For five studies (California,[24] Florida,[25] Georgia,[26] Nova Scotia,[11] New York[27]) the adjustment for time was based on changes in the crash rates of older drivers, because we had only data from one time period before the GDL law and one after. For four studies (Maryland,[28] Michigan,[29] Pennsylvania,[30] Texas[31]) the adjustment for time was based on data for teenage drivers, because data was available for three or more time intervals. For two studies (Ohio,[32] Wisconsin[33]) the adjustment used data from both teenage and older drivers, because data was available for three or more time intervals and data was available for older drivers.

To clarify we will describe what we did for one study from Nova Scotia.[11] For our meta-analysis we needed to extract an adjusted rate ratio with a CI for the association between the GDL law and the crash rate. But this information was not in the paper. Table 3 of that paper provided data for counts of Nova Scotia drivers in crashes with an injury for the years 1993 and 1995 (table 1). Nova Scotia's new GDL began in October of 1994. We created variables for age group and the interaction between age 17 and the GDL law. Then we used Poisson regression to estimate the aRR. This was adjusted for the linear trend in crash rates for persons age 25 years and older from 1993 to 1995.

We used inverse-variance methods to produce pooled estimates of the aRRs from each study using Stata V.12. Random-effect estimates were calculated using the method of DerSimonian and Laird.[34] Fixed effect estimates were also obtained. The Cochran Q-statistic was used to test the hypothesis that rate ratios were homogeneous across studies.[35] We calculated I^2, an estimate of the percent of total variation between studies due to heterogeneity rather than chance.[36] To test for publication bias, funnel plots were inspected and Egger's test for asymmetry was used.[37] To identify characteristics associated with heterogeneity, we used subgroup analyses for the following variables (1) outcome type (crash with injury, crash with death), (2) entry age for learner permit phase (<16 years, 16), (3) entry age for intermediate phase (16 years, >16), (4) night-time driving restriction (starting at 21 : 00 or 22 : 00; starting at 23 : 00, midnight or 1 : 00; none or no change) and (5) number of young passengers allowed (0, 1, 2, 3 or more). Because tests of heterogeneity are statistically weak when there are few studies, we used $p<0.1$ as our criteria to judge that there was heterogeneity.

When a GDL is passed, its effects may not be immediate for several reasons. One is that some people might already have a license and may be grandfathered in under the law. For example, a 16-year-old may be allowed to continue to drive under the old law provisions after the new law is passed. For this reason, some studies use data until the time of GDL implementation. Then after the GDL goes into effect, they omit 1 year of data, using information for 16 year olds only after the law has been effect for over a year. We attempted to deal with this issue in our analyses. For example, for age 16 years there were 12 studies. Of these, six omitted the first year after the law went into effect or presented data in such a way that we could omit that first year. For a further two studies, the first year after the law went into effect could not be omitted, but there were 5 years of data available after the law went into effect, and thus 16-year-olds were fully covered by the law in four of the 5 years of post-law data. This means that any dilution of the GDL effect induced by including the first year after implementation should be relatively small in 5 years of data. But in four jurisdictions, Florida, Nova Scotia, Ohio, and Pennsylvania, we could not exclude a full year of data after the law went into effect and we did not have 5 years of data after the law went into effect. For Florida, a 6 month period after the law went into effect was excluded. For Nova Scotia, 2 months were excluded. For Ohio, 6 months were excluded. No post-law time was excluded for Pennsylvania. Thus, in theory, some dilution of the GDL effect might be found in these four studies. To find out if there was evidence for this dilution of effect, we used a test of heterogeneity to compare the pooled aRR in the eight studies where one post-law year was excluded, or 5 years of post-law data was used, with the pooled aRR in the four studies where this could not be done.

For drivers age 17 years, we followed the same procedure, except we tried to exclude 2 years of data after GDL implementation. There were eight studies for this age group. For three, we could either exclude 2 years of data after GDL passage or use 5 years of data after passage. We could not do this for the other five studies. Again, we compared the aRR estimates from the first three studies with the other five.

For drivers age 18 years there were only four studies. California excluded the third year and used the fourth year to the eighth year after GDL implementation. Florida excluded only 6 months. Georgia excluded no time, but used 5.5 years of data after implementation. Wisconsin excluded 2.25 years of post-law data. We did not perform the test of heterogeneity in this small group of four studies.

RESULTS

The literature search identified 1397 papers, but 1253 were excluded as not relevant based upon their titles (figure 1). Another 97 papers were removed after reading the abstract and the remaining 47 papers were read. We identified 12 studies that could provide crash counts and population estimates for age 16,[111524–33] eight for age 17,[1124–27303233] and four for age 18.[24–2633] We conducted new analyses to estimate adjusted rate ratios with CIs for GDL presence for 11 of the 12 studies for adolescents age 16 years. For North Carolina[15] the data were not available for a new analysis. We conducted new analyses for all eight studies for age 17, and all four studies for age 18.

Adolescents age 16 years

Data were used from 11 US states (California,[24] Florida,[25] Georgia,[26] Maryland,[28] Michigan,[29] New York,[27] North Carolina,[15] Ohio,[32] Pennsylvania,[30] Texas,[31] Wisconsin[33]) and one Canadian province (Nova Scotia[11]) (tables 2 and 3). Nine studies[111524–2933] were published in peer-reviewed journals and three[30–32] were reports. In these jurisdictions the earliest GDL law was implemented in July 1996 in Florida and the latest in September 2003 in New York. The entry age for a learner permit stayed the same in 10 jurisdictions, was reduced from 15 to 14 years and 9 months in Michigan, and was reduced from 16 years to 15 years and 6 months in Ohio. The length of the learner period was extended to 6 months or less in ten jurisdictions, and 12 months in two jurisdictions. The entry age for the new intermediate phase after GDL implementation was 16 years in eight jurisdictions, older than 16 and less than 16.5 in two, and 16.5 in two. North Carolina did not allow beginners to drive unsupervised after 21 : 00, and night-time restriction was 23 : 00 or later in other jurisdictions. Maryland and New York implemented a night-time restriction before their GDL laws. Three jurisdictions mandated no more than one young passenger, New York allowed two and Georgia allowed three; the rest did not have young passenger restrictions. Of 12 GDL laws first implemented between 1996 and 2003 in our meta-analysis, 3 (25%) restricted both night driving and the number of passengers, compared with 9/37 (24%) of all US GDL laws during the same period.[23] The outcome was injury crashes for nine studies,[11152527–303233] and fatal crashes for three.[242631]

The aRR associated with GDL implementation ranged from 0.64 in Georgia to 0.89 in Florida. The crash rate was less in the presence of GDL compared with what would have been expected without GDL: pooled random-effects aRR 0.78 (95% CI 0.72 to 0.84) (figure 2). The Q-statistic indicated that the individual aRRs did not estimate the same effect ($p<0.001$) and I^2 was 91%, indicating that most of the difference between estimates could not be ascribed to chance variation. The pooled fixed-effects aRR was 0.84 (95% CI 0.82 to 0.85) We found no evidence of publication bias: p=0.17.

In only one subgroup analysis did we find that pooled random-effect aRR estimates showed statistically significant variation (table 4). The pooled aRR was 0.83 using the nine jurisdictions where adolescents could obtain a learner permit before reaching age 16, and 0.68 in the three jurisdictions where adolescents had to wait until after reaching 16; $p<0.001$ for a test that these two estimates differed. Subgroup aRR estimates did not differ significantly according to outcome type, entry age for the intermediate phase, category of night-time driving restrictions, or the allowed number of young passengers.

The pooled aRR was 0.79 among the four jurisdictions (Florida, Nova Scotia, Ohio and Pennsylvania) where less than one full year of data right after GDL implementation could be excluded from analysis and 0.78 using the eight remaining jurisdictions where at least 1 year of post-GDL data could be excluded from analysis or there were at least 5 years of data after GDL passage; p=0.91 for a test that these two estimates differed.

Adolescents age 17 years

Useable estimates came from seven US states (California,[24] Florida,[25] Georgia,[26] New York,[27] Ohio,[32] Pennsylvania,[30] Wisconsin[33]) and one Canadian province (Nova Scotia[11]) (tables 2 and 3). Six[1124–2733] were peer-reviewed articles and two[3032] were reports. All also provided estimates for 16-year-olds, so characteristics of their GDL laws have already been summarised.

The aRR associated with GDL implementation ranged from 0.81 in Georgia to 1.03 in Nova Scotia. The pooled random-effects aRR was 0.94 (95% CI 0.93 to 0.96) (figure 3). The p value for the Q-statistic was 0.44 and I^2 was less than 1%, indicating homogeneity among jurisdictional aRR estimates. The pooled fixed-effects aRR was 0.94 (95% CI 0.93 to 0.96). We found no evidence of publication bias: p=0.85. Subgroup analyses were not conducted for this age group, because there was no evidence of heterogeneity between jurisdictional estimates and the pooled association between GDL laws and the aRR was close to 1.0.

The pooled aRR was 0.92 using the three jurisdictions (California, Georgia and Wisconsin) where we could exclude two full years of data after GDL passage or there were at least 5 years of data after GDL implementation and 0.94 among the remaining five jurisdictions where less than two full years of data after GDL passage could be excluded from analysis; p=0.56 for a test that these two estimates differed.

Adolescents age 18 years

Data were available from four US states (California,[24] Florida,[25] Georgia,[26] Wisconsin[33]) (tables 2 and 3). The traffic crash rate ratio associated with GDL implementation ranged from 0.97 in Georgia and Wisconsin to 1.17 in California. The pooled random-effects aRR was 1.00 (95% CI 0.95 to 1.04) (figure 4). The p value for the Q-statistic was 0.18 and I^2 was 39%, indicating low heterogeneity among aRRs. The pooled fixed-effects aRR was 1.00 (95% CI 0.97 to 1.02). There was no evidence of publication bias: p=0.41. Subgroup analyses were not conducted for this age group, as there were only four studies, and the pooled association between GDL laws and crash rates was close to one.

Variation of age-specific pooled estimates

The random-effects pooled aRR associated with GDL laws was 0.78 for those age 16 years, 0.94 for those age 17 and 1.00 for those age 18; a test that these estimates differed was statistically significant, p<0.001. We also tested whether the aRR for 16-year-olds was different from that for 17-year-olds among the eight studies with estimates for both these age groups. The pooled random-effects aRR was 0.78 (95% CI 0.71 to 0.86) for age 16 and 0.94 (95% CI 0.93 to 0.96) for age 17; p value for a test of difference was <0.001. Among the four studies with results for all age groups, the aRR was 0.82 (95% CI 0.75 to 0.90) for age 16 years, 0.93 (95% CI 0.91 to 0.96) for age 17 and 1.00 (95% CI 0.95 to 1.04) for age 18; these estimates were statistically different, p<0.001.

DISCUSSION

Our meta-analysis estimated that adolescents aged 16 years experienced a 22% (95% CI 16% to 28%) reduction in crash rates, while among 17-year-olds the rate reduction was smaller, 6% (95% CI 4% to 7%), and among teenagers aged 18 years the rate changed little after GDL implementation. The apparent difference in GDL effects among those age 16 and those age 17 years is probably not due to the different study jurisdictions, as the pooled random-effects aRR for 16-year-olds was 0.78 using the eight studies with results for both ages 16 and 17, the same as the pooled aRR of 0.78 using all 12 studies.

Perhaps the most important limitation of this meta-analysis was the small number of studies available with age-specific data for ages 17 and 18 years; there were reports available from 12 jurisdictions for age 16 years, but only from eight jurisdictions for age 17 and four for age 18. Because we had few studies to summarise, all results are exploratory and those for adolescents age 18 years are particularly unreliable due to the small number of studies. Second, it would be ideal to study the same outcomes for every jurisdiction as it is possible that associations with GDLs might vary with the type of crash outcome. Among the 12 studies for age 16 years, the rate ratio for GDL laws varied somewhat according to whether the outcome involved injury (aRR 0.79) or death (aRR 0.72), but the difference in these rate ratios was modest and not statistically different (p=0.44, table 4). Another limitation is that we could not exclude 1 to 3 years of data after GDL implementation for all studies, allowing us to examine whether GDL effects might be stronger when all drivers of a given age are covered by the laws. To address this problem, we compared aRRs based on excluding 1 or 2 years of data after GDL passage or based on at least 5 years of data after GDL passage, with estimates from jurisdictions where the years immediately after GDL passage had to be included. These estimates were similar. A national evaluation of 1996–2007 US fatal crashes compared the immediate effect of GDL with 1-year delay for age 17, and 2-year delay for age 18, and reported similar estimates.[17] Another limitation is that our estimates may be subject to residual confounding. GDL effectiveness should ideally be estimated with many repeated measures of crash rates before and after GDL implementation. We conducted new analyses for 11 of the 12 studies for age 16 by using methods to control for temporal changes in crash rates unrelated to GDL policies. However, some traffic safety factors may affect adolescents and adults differently, and our ability to control for temporal trends was limited by the available data years in the original research. Nevertheless, our estimates were comparable to nationwide US evaluations using more than 10 years of crash rates.[16,17,19,20] Another limitation is that none of the studies selected for meta-analysis contained any information about the amount of driving done by adolescents.

Our estimate of a 22% (95% CI 16% to 28%) reduction of traffic crash rates among 16 year olds is consistent with previous studies for this age group for the entire USA. A review of collision claims for vehicles less than 4-years-old during 1996 through 2006 reported a 22% reduction (95% CI 18% to 27%) for states with good GDL ratings from the Insurance Institute for Highway Safety and a 17% reduction (95% CI 12% to 31%) for states with fair GDL ratings.[20] In an analysis of crashes with a death during 1994–2004, GDL polices that included five or more of seven GDL components were associated with an 18–21% reduction in crash rates.[19] Another study of all fatal crashes during 1996–2007 reported a 41%

reduction in crash rates for states with a good GDL rating and an 18% reduction for states with a fair GDL rating.[17] Another analysis of 1986–2007 fatal crashes in the USA reported that among those age 16 years, GDL was associated with a 16% reduction (95% CI 6% to 25%) in crash rates for jurisdictions with either a night-time driving restriction starting before 1 : 00 or a passenger restriction allowing no more than one young passenger, and a 26% reduction (95% CI 16% to 35%) for jurisdictions with both restrictions.[16] In a Cochrane review, five GDL programmes were summarised with a median decrease of 15.5% (range 8% to 27%) for the adjusted rate of all crashes during the first year and 21% (range 2% to 46%) for the adjusted rate of crashes with an injury among 16 year olds.[18]

Our estimate of association (aRR 0.94, 95% CI 0.93 to 0.96) between GDL and traffic crash rates among 17 year olds is consistent with previous studies for this age group for the entire USA. A study of all fatal crashes during 1996–2007 reported a rate ratio of 0.81 for states with a good GDL rating and 0.97 for states with a fair GDL rating.[17] Another study of fatal crashes during 1986–2007 reported an aRR of 0.98 (95% CI 0.92 to 1.04) for GDL with night-time driving or passenger restriction, and an aRR of 0.91 (95% CI 0.83 to 1.01) for GDL with both restrictions.[16]

Our study did not find that GDL implementation was related to traffic crash rates among 18 year olds (aRR 1.00, 95% CI 0.95 to 1.04). A study of all fatal crashes for 18-year-olds in the USA during 1996–2007 reported a rate ratio of 0.96 for states with a good GDL rating and 1.03 for states with a fair GDL rating.[17] However, another study of all fatal crashes in the US during 1986–2007 reported that GDL with either a night-time driving restriction or passenger restriction was associated with a 10% increase (aRR 1.10, 95% CI 1.03 to 1.18) in fatal crash involvements among those age 18.[16] Further research is needed to evaluate whether GDL negatively affects 18 year olds.

CONCLUSION

GDL implementation was associated with a 22% reduction in traffic crash rates among 16 year olds, but only a 6% reduction in rates among 17 year olds. GDL implementation was unrelated to crash rates among 18 year olds, but this exploratory finding was based upon a sample of only four jurisdictions and should be treated with caution.

Acknowledgments

We express appreciation to Michele Fields and Laurel Sims at the Insurance Institute for Highway Safety for their assistance in describing graduated driver licensing laws; and to anonymous reviewers for their constructive comments.

Funding MZ and JHC received support from grants (R21CE0018205, R49CE001170) from the US Centers for Disease and Prevention, National Center for Injury Prevention and Control (http://www.cdc.gov/injury/). The funders had no role in study design, data collection and analysis, decision to publish or preparation of the manuscript.

References

1. World Health Organization. Global status report on road safety:time for action. Geneva: World Health Organization; 2009.

2. Patton GC, Coffey C, Sawyer SM, et al. Global patterns of mortality in young people: a systematic analysis of population health data. Lancet. 2009; 374:881–92. [PubMed: 19748397]
3. Insurance Institute for Highway Safety. Fatality Facts 2010: Teenagers. Arlington, VA: Insurance Institute for Highway Safety; 2012.
4. Simons-Morton B, Lerner N, Singer J. The observed effects of teenage passengers on the risky driving behavior of teenage drivers. Accid Anal Prev. 2005; 37:973–82. [PubMed: 15921652]
5. Jonah BA, Dawson NE. Youth and risk: age differences in risky driving, risk perception, and risk utility. Alcohol Drugs Driving. 1987; 3:13–29.
6. Hedlund J. Novice teen driving: GDL and beyond. J Safety Res. 2007; 38:259–66. [PubMed: 17478196]
7. Gregersen NP, Berg HY, Engstrom I, et al. Sixteen years age limit for learner drivers in Sweden—an evaluation of safety effects. Accid Anal Prev. 2000; 32:25–35. [PubMed: 10576673]
8. Gregersen NP, Nyberg A, Berg HY. Accident involvement among learner drivers—an analysis of the consequences of supervised practice. Accid Anal Prev. 2003; 35:725–30. [PubMed: 12850073]
9. Twisk DAM, Stacey C. Trends in young driver risk and countermeasures in European countries. J Saf Res. 2007; 38:245–57.
10. Begg DJ, Stephenson S, Alsop J, et al. Impact of graduated driver licensing restrictions on crashes involving young drivers in New Zealand. Inj Prev. 2001; 7:292–6. [PubMed: 11770654]
11. Mayhew DR, Simpson HM, Groseilliers MD, et al. Impact of the graduated driver licensing program in Nova Scotia. J Crash Prev Inj Control. 2001; 2:179–92.
12. Senserrick, TM.; Whelan, M. Graduated driver licensing: effectiveness of systems and individual components. Victoria, Australia: Monash University Accident Research Centre; 2003.
13. Shope JT, Molnar LJ, Elliott MR, et al. Graduated driver licensing in Michigan: early impact on motor vehicle crashes among 16-year-old drivers. JAMA. 2001; 286:1593–8. [PubMed: 11585482]
14. Ben-Ari O, Lotan T. The contribution of a novel intervention to enhance safe driving among young drivers in Israel. Accid Anal Prev. 2011; 43:352–9. [PubMed: 21094333]
15. Foss RD, Feaganes JR, Rodgman EA. Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. JAMA. 2001; 286:1588–92. [PubMed: 11585481]
16. Masten SV, Foss RD, Marshall SW. Graduated driver licensing and fatal crashes involving 16- to 19-year-old drivers. JAMA. 2011; 306:1098–103. [PubMed: 21917580]
17. McCartt, AT.; Teoh, ER.; Fields, M., et al. Graduated licensing laws and fatal crashes of teenage drivers: a national study. Arlington, VA: Insurance Institute for Highway Safety; 2009.
18. Russell K, Vandermeer B, Hartling L. Graduated driver licensing for reducing motor vehicle crashes among young drivers. Cochrane Database Syst Rev. 2011; (10):CD003300. [PubMed: 21975738]
19. Chen LH, Baker SP, Li G. Graduated driver licensing programs and fatal crashes of 16-year-old drivers: a national evaluation. Pediatrics. 2006; 118:56–62. [PubMed: 16818549]
20. Trempel, RE. Graduated driver licensing laws and insurance collision claim frequencies of teen drivers. Arlington, VA: Highway Loss Data Institute; 2009.
21. Shope JT. Graduated driver licensing: review of evaluation results since 2002. J Safety Res. 2007; 38:165–75. [PubMed: 17478187]
22. Williams AF, Shults RA. Graduated Driver Licensing Research, 2007-present: a review and commentary. J Safety Res. 2010; 41:77–84. [PubMed: 20497792]
23. Insurance Institute for Highway Safety. Graduated driver licensing effective dates. Arlington, VA: Insurance Institute for Highway Safety; 2012.
24. Males M. California's graduated driver license law: Effect on teenage drivers' deaths through 2005. J Safety Res. 2007; 38:651–9. [PubMed: 18054596]
25. Ulmer RG, Preusser DF, Williams AF, et al. Effect of Florida's graduated licensing program on the crash rate of teenage drivers. Accid Anal Prev. 2000; 32:527–32. [PubMed: 10868755]
26. Rios A, Wald M, Nelson SR, et al. Impact of Georgia's Teenage and Adult Driver Responsibility Act. Ann Emerg Med. 2006; 47:361–369.

27. Zhu M, Chu H, Li G. Effects of graduated driver licensing on licensure and traffic injury rates in Upstate New York. Accid Anal Prev. 2009; 41:531–5. [PubMed: 19393803]
28. Kirley BB, Feller A, Braver E, et al. Does the Maryland graduated driver licensing law affect both 16-year-old drivers and those who share the road with them? J Safety Res. 2008; 39:295–301. [PubMed: 18571571]
29. Shope JT, Molnar LJ. Michigan's graduated driver licensing program: evaluation of the first four years. J Safety Res. 2004; 35:337–44. [PubMed: 15288567]
30. Coben, JH.; Mckay, MP. Evaluation of the effectiveness of Pennsylvania's graduated driver licensing program. Pittsburgh, PA: The Center for Violence and Injury Control, Allegheny-Singer Research Institute; 2003.
31. Willis, DK. Fatal crashes involving 16 year-old Texas drivers Pre- and Post-GDL: Who, when, where, and why?. College Station: Texas Transportation institute; 2006.
32. Ohio Department of Public Safety. Evaluation of Ohio's graduated driver licensing program. Columbus, OH: Ohio Department of Public Safety; 2001.
33. Fohr SA, Layde PM, Guse CE. Graduated driver licensing in Wisconsin: does it create safer drivers? Wisconsin Medical Journal. 2005; 104:31–6. [PubMed: 16294597]
34. DerSimonian R, Laird N. Meta-analysis in clinical trials. Control Clin Trials. 1986; 7:177–88. [PubMed: 3802833]
35. Deeks, JJ.; Altman, DG.; Bradburn, MJ. Statistical methods for examing heterogeneity and combining results from several studies in meta-analysis. In: Egger, M.; Smith, GD.; Altman, DG., editors. Systematic reviews in health care: meta-analysis in context. London: BMJ Publishing Group; 2001. p. 285-312.
36. Higgins JPT, Simon GT, Deeks JJ, et al. Measuring inconsistency in meta-analyses. BMJ. 2003; 327:557–60. [PubMed: 12958120]
37. Egger M, Smith GD, Schneider M, et al. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997; 315:629–34. [PubMed: 9310563]

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What is already known on the subject

- Graduated Driver Licensing has been reported to reduce involvement in a vehicle crash as a driver by approximately 15–40% for adolescents aged 16 years.
- Few studies have examined 17 and 18 year old drivers.

What this study adds

- Adolescents age 17 years received less benefit from GDL laws than adolescents age 16 years.
- GDL implementation showed little association with crashes among 18 year olds, but this exploratory finding was based upon a sample of only four jurisdictions and should be treated with caution.

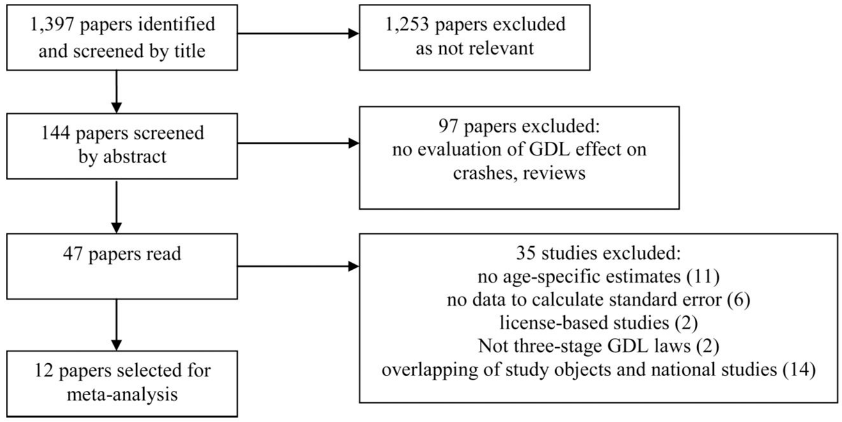

Figure 1.
Flow chart of study selection for data extraction.

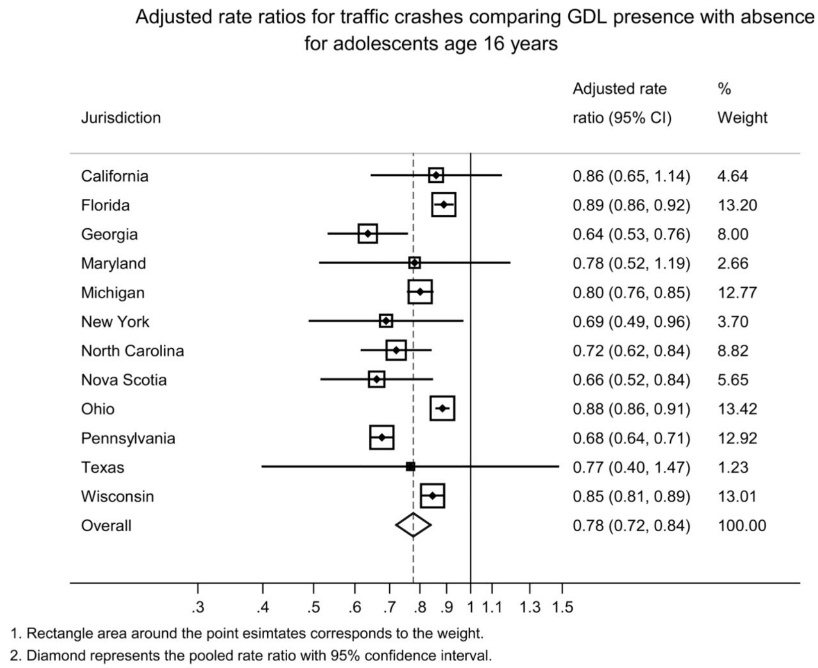

Figure 2.

Adjusted rate ratios for traffic crashes comparing graduated driver licensing (GDL) presence with absence for adolescents age 16 years.

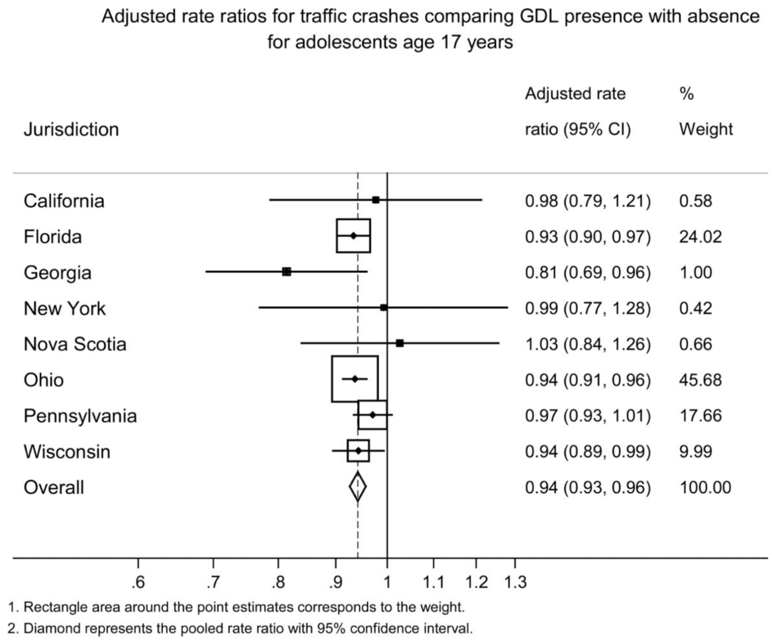

Figure 3.

Adjusted rate ratios for traffic crashes comparing graduated driver licensing (GDL) presence with absence for adolescents age 17 years

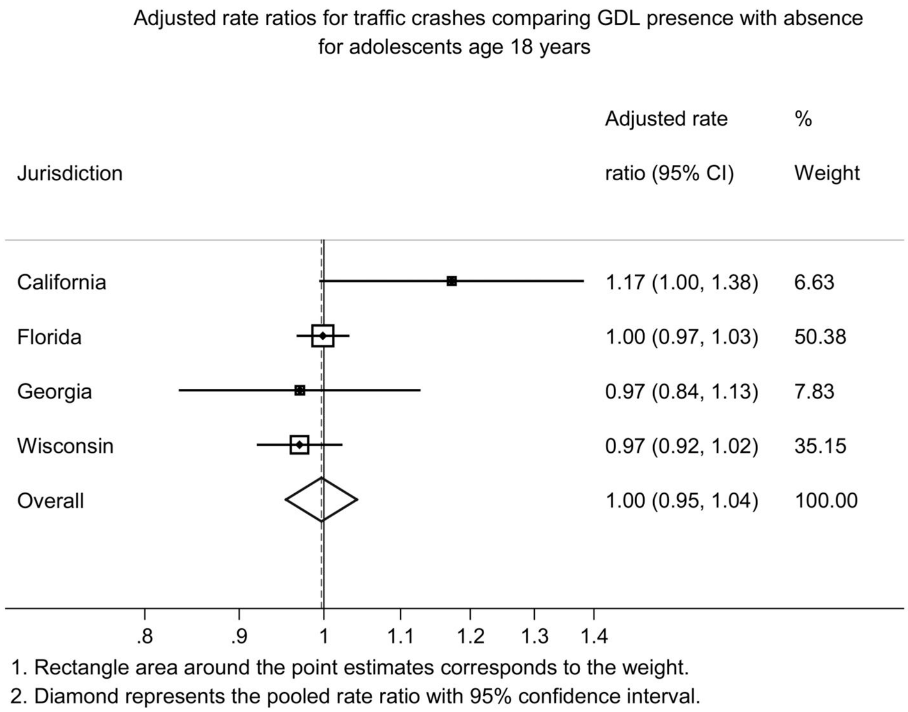

Figure 4.

Adjusted rate ratios for traffic crashes comparing graduated driver licensing (GDL) presence with absence for adolescents age 18 years.

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Table 1

Data from one study of graduated driver licensing in Nova Scotia

Graduated driver licensing status	Year	Age (years)	Drivers in crash with injury	Person-years	Crash rate per 10000 person-years
Absent	1993	16	167	12700	131.50
Absent	1993	17	201	13400	150.00
Absent	1993	25 or older	4233	661700	63.97
Present	1995	16	110	12620	87.16
Present	1995	17	193	12501	154.39
Absent	1995	25 or older	4317	672986	64.15

GDL, Graduated Driver Licensing.

Table 2

Characteristics of the 12 studies which provided useable age-specific data for meta-analysis

Jurisdiction	First author, year	Graduated driver licensing status	Age for learner permit (years, month)	Length of learner period (months)	Practice hours	Night-time driving restrictions	No. of young passengers allowed	Age for intermediate phase (years, month)	Age for full licensure phase (years, month)
California	Males, 2007	Absent	15	1	None*	None*	None*	NA	16
		Present	15	6	50	Midnight	0	16	17
Florida	Ulmer, 2000	Absent	15	None*	None*	None*	None*	NA	16
		Present	15	6	None*	23 : 00	None*	16	18
Georgia	Rios, 2006	Absent	15	None*	None*	None*	None*	NA	16
		Present	15	12	None*	1 : 00	3	16	18
Maryland	Kirley, 2008	Absent	15, 9 month	0.5	None*	Midnight	None*	16	17, 9 month
		Present	15, 9 month	4	40	Midnight	None*	16, 1 month	17, 7 month
Michigan	Shope, 2004	Absent	15	1	None*	None*	None*	NA	16
		Present	14, 9 month	6	50	Midnight	None*	16	17
New York	Zhu, 2010	Absent	16	None*	None*	21 : 00	None*	16	17
		Present	16	Up to 6	20	21 : 00	2	16, up to 6 month	17
North Carolina	Foss, 2001	Absent	15	None*	None*	None*	None*	NA	16
		Present	15	12	None*	21 : 00	None*	16	16, 6 month
Nova Scotia	Mayhew, 2001	Absent	16	2	None*	None*	None*	NA	16, 2 month
		Present	16	6	None* 0	Midnight	None*	16, 6 month	18, 6 month
Ohio	Ohio DPS, 2001	Absent	16	None*	None*	None*	None*	NA	16
		Present	15, 6 month	6	50	1 : 00	None*	16	17
Pennsylvania	Coben, 2003	Absent	16	None*	None*	23 : 00	None*	16	17
		Present	16	6	50	23 : 00	None*	16, 6 month	17
Texas	Willis, 2006	Absent	15	None*	None*	None*	None*	NA	16
		Present	15	6	None*	Midnight	1	16	16, 6 month
Wisconsin	Fohr, 2005	Absent	15, 6 month	None*	None*	None*	None*	NA	16

Jurisdiction	First author, year	Graduated driver licensing status	Age for learner permit (years, month)	Length of learner period (months)	Practice hours	Night-time driving restrictions	No. of young passengers allowed	Age for intermediate phase (years, month)	Age for full licensure phase (years, month)
		Present	15, 6 month	6	30	Midnight	1	16	16, 9 month

*No restrictions.

GDL, Graduated Driver Licensing; NA: not applicable.

Table 3

Crude and adjusted age-specific rate-ratios for each study

Jurisdiction	Outcome used*	Age (years)	Count of outcomes†	Time period before GDL‡	GDL onset (month/year)	Time period after GDL‡	Crude rate before GDL§	Crude rate after GDL§	Crude rate ratio	Adjusted rate ratio (95% CI)	Adjustment method¶	New analysis done**
California	Driver deaths	16	208	1/95–6/98	7/98	7/99–12/05	4.6	3.9	0.86	0.86 (0.65 to 1.14)	Older drivers	Yes
		17	348	1/95–6/99		7/00–12/05	7.0	7.1	1.02	0.98 (0.79 to 1.21)		
		18	610	1/95–6/00		7/01–12/05	11.1	14.0	1.26	1.17 (1.00 to 1.38)		
Florida	Crash with injury/death	16	10958	1/95–12/95	7/96	1/97–12/97	3228	2902	0.90	0.89 (0.86 to 0.92)	Older drivers	Yes
		17	14323				4299	4056	0.94	0.93 (0.90 to 0.97)		
		18	16302				4928	4976	1.01	1.00 (0.97 to 1.03)		
Georgia	Crash with death	16	547	1/92–6/97	7/97	7/97–12/02	57.0	36.1	0.63	0.64 (0.53 to 0.76)	Older drivers	Yes
		17	590				54.8	44.4	0.81	0.81 (0.69 to 0.96)		
		18	724				62.6	60.4	0.97	0.97 (0.84 to 1.13)		
Maryland	Injured drivers	16	920	1/96–12/98	7/99	1/01–12/03	294	142	0.48	0.78 (0.52 to 1.19)	Teenage drivers	Yes
Michigan	Crash with injury/death	16	23824	1/96–12/96	4/97	1/98–12/01	4517	3038	0.67	0.80 (0.76 to 0.85)	Teenage drivers	Yes
New York	Injured drivers	16	162	1/01–12/01	9/03	1/05–12/05	81.4	55.3	0.68	0.69 (0.49 to 0.96)	Older drivers	Yes
		17	313				134.0	131.2	0.98	0.99 (0.77 to 1.28)		
North Carolina	Crash with injury	16	NA	1/96–12/96	12/97	1/99–12/99	370	270	0.72	NA	None	No
Nova Scotia	Crash with injury/death	16	277	1/93–12/93	10/94	1/95–12/95	1315	872	0.66	0.66 (0.52 to 0.84)	Older drivers	Yes
		17	394				1500	1544	1.03	1.03 (0.84 to 1.26)		
Ohio	Crash with injury	16	57149	1/90–12/97	7/98	1/99–12/99	4110	3622	0.88	0.88 (0.86 to 0.91)	Older and teenage drivers	Yes
		17	67832				4757	4441	0.93	0.94 (0.91 to 0.96)		
Pennsylvania	Crash with injury	16	17384	1/96–12/99	1/00	1/00–12/00	2238	1465	0.65	0.68 (0.64 to 0.71)	Teenage drivers	Yes
		17	25090				3065	2881	0.94	0.97 (0.93 to 1.01)		
Texas	Crash with death	16	360	1/00–12/01	1/02	1/03–12/04	31.2	23.2	0.74	0.77 (0.40 to 1.47)	Teenage drivers	Yes
Wisconsin	Crash with injury	16	8336	1/99–12/99	9/00	1/02–12/03	4014	3073	0.77	0.85 (0.81 to 0.89)	Older and teenage drivers	Yes
		17	6148	1/99–12/99		1/03–12/03	4061	3431	0.84	0.94 (0.89 to 0.99)		
		18	6180	1/99–12/99		1/03–12/03	3994	3473	0.87	0.97 (0.92 to 1.02)		

*We used age-specific counts of drivers in this order of preference: (1) crash with at least one injury, (2) injured drivers, (3) crash with at least one death, (4) drivers who died.

†Overall count of outcome events.

‡Rate information came from these time periods before and after GDL onset.

§Rate per 100 000 person-years based on population estimates.

¶Except for North Carolina, rate ratios were adjusted for change in crash rates over time using data from one of three groups: (1) older drivers; (2) teenage drivers; (3) older and teenage drivers.

**Yes means that we extracted data to re-estimate an adjusted rate ratio or CI that was not in the original report.

GDL, Graduated Driver Licensing.

Table 4

Subgroup estimates of the random-effect pooled adjusted rate ratios for crash rates under GDL laws compared with expected rates without GDL laws, for adolescents age 16 years

Subgroup	Category	Random-effect pooled adjusted rate ratio	95% CI	p Value for a test that the adjusted rate ratios are the same*
Outcome type	Crash with injury	0.79	0.73 to 0.85	0.44
	Crash with death	0.72	0.58 to 0.90	
Entry age for learner permit phase	<16 years	0.83	0.79 to 0.87	<0.001
	16 years	0.68	0.64 to 0.71	
Entry age for intermediate phase	16 years	0.81	0.75 to 0.86	0.41
	>16 years	0.74	0.61 to 0.90	
Night-time driving restriction	Starting at 21 : 00 or 22 : 00	0.72	0.62 to 0.84	0.54
	Starting after 22 : 00	0.79	0.73 to 0.86	
	None or no change	0.72	0.56 to 0.94	
Number of young passengers allowed	0	0.86	0.65 to 1.14	0.19
	1	0.85	0.81 to 0.89	
	2	0.69	0.49 to 0.96	
	3 or more	0.76	0.69 to 0.84	

*p Value for a test of homogeneity using the inverse variance method. A small p value is evidence that the adjusted rate ratios vary more than expected if the GDL laws had similar effects in similar populations.

GDL, Graduated Driver Licensing.