GRADUATED LICENSING LAWS AND FATAL CRASHES OF TEENAGE DRIVERS: A NATIONAL STUDY

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ABSTRACT

Objectives: The objective of the current study was to quantify the effects of the strength of US state graduated driver licensing laws and specific licensing components on the rate of teenage driver fatal crash involvements per 100,000 teenagers during 1996-2007. The strengths of state laws were rated good, fair, marginal, or poor based on a system developed previously by the Insurance Institute for Highway Safety.

Methods: Analysis was based on quarterly counts of drivers involved in fatal crashes. Associations of overall ratings and individual licensing components with teenage crash rates were evaluated using Poisson regression, with the corresponding fatal crash rate for drivers ages 30-59 controlling for state- or time-dependent influences on crash rates unrelated to graduated licensing laws.

Results: Compared with licensing laws rated poor, laws rated good were associated with 30 percent lower fatal crash rates among 15-17 year-olds. Laws rated fair yielded fatal crash rates 11 percent lower. The longer the permit age was delayed, or the longer the licensing age was delayed, the lower the estimated fatal crash rates among 15-17 year-olds. Stronger nighttime restrictions were associated with larger reductions, and reductions were larger for laws limiting teenage passengers to zero or one than laws allowing two or more teenage passengers or laws without passenger restrictions. After the effects of any related delay in licensure were accounted for, an increase in the minimum learner’s permit holding period showed no association with fatal crash rates. An increase in required practice driving hours did not appear to have an independent association with fatal crash rates.

Conclusions: Graduated licensing laws that include strong nighttime and passenger restrictions and laws that delay the learner’s permit age and licensing age are associated with lower teenage fatal crash rates. States that adopt such laws can expect to achieve substantial reductions in crash deaths.

Keywords: Graduated driver licensing laws; Motor vehicle crashes; Teenage drivers; Driver’s license; Learner’s permit; Nighttime and passenger restrictions

INTRODUCTION

Teenage Crash Risks

In 2008, 4,054 teenagers died in the United States from injuries sustained in motor vehicle crashes. Such injuries are by far the leading cause of death among people 13-19 years old. In 2006, the latest year for which data are available, 36 percent of all deaths among 16-19 year-olds occurred in motor vehicle crashes (Insurance Institute for Highway Safety (IIHS), 2009a).

Although they drive less than all but the oldest drivers, teenage drivers have elevated rates of crashes compared with adult drivers. For crashes of all severities, the crash rate per mile driven for 16-19 year-olds is four times as high as the rate for drivers 20 and older (IIHS, 2008b). The rate is highest at age 16, nearly twice as high as for 18-19 year-olds. The fatal crash rate per mile driven also is highest for drivers ages 16-19 — 7 fatal crashes per 100 million miles compared with 2 for drivers 20 and older. Fatal crashes of young drivers often occur when other young people are in the vehicle, so teenagers are disproportionately involved in crashes as passengers as well as drivers; 61 percent of teenage passenger deaths in 2007 occurred in vehicles driven by another teenager.

Crash rates for young drivers are high because of their immaturity combined with their inexperience with driving. The crash risk of teenage drivers is particularly high during the first months of licensure (Mayhew, Simpson, and Pak, 2003; McCartt et al., 2003), when their lack of experience behind the wheel makes it difficult for them to recognize and respond to hazards. Immaturity is apparent in young drivers' risky driving practices such as speeding. A study of nonfatal crashes of newly licensed teenage drivers in Connecticut found that important contributing factors were speeding, losing control of the vehicle or sliding, and failing to detect another vehicle or traffic control device, often due to distraction or inattention (Braitman et al., 2008). Teenage crash risk is particularly elevated at night and when carrying teenage passengers (Chen et al., 2000; Doherty et al., 1998; Ferguson et al., 2007; Preusser et al., 1998; Ulmer et al., 1997; Williams, 2003; Williams et al., 2005).

Until the mid-1990s, most US states allowed teenagers to obtain unrestricted driver's licenses at earlier ages than in most other countries, and little driving experience typically was required prior to licensure. Starting with Florida in 1996, most states have modified their laws to require beginning drivers to complete a series of stages before obtaining full-privilege licenses. Graduated driver licensing (GDL) is designed to delay full licensure while allowing beginners to obtain initial experience under lower risk conditions. There are three stages: an extended learner phase of driving under adult supervision, an intermediate license (once the driving test is passed) that limits unsupervised driving in high-risk situations, and an unrestricted driver's license available after completion of the first two stages. Beginners must remain in each of the first two stages for specific minimum time periods. All but one state have enacted three-stage graduated licensing systems for young drivers, but the systems vary in strength based on what requirements are included and how long they last.

Crash Effects of Graduated Licensing Laws

The benefits of graduated licensing in reducing crashes of young drivers have been demonstrated in research conducted in the United States, Canada, and New Zealand. In jurisdictions that have adopted elements of graduated licensing, studies have found overall crash reductions among young teenagers (typically 16 year-olds) of about 10-30 percent (Fohr et al., 2005; Foss et al., 2001; Hallmark et al., 2008; Mayhew, Simpson, Desmond, et al., 2003; Neyens et al., 2008; Shope and Molnar, 2004; Ulmer et al., 2000). Most studies have calculated crash rates per capita; reductions generally have been greater when crash rates were calculated per capita than when calculated per licensed driver (Shope, 2007). Where nighttime restrictions have been examined, they have been associated with 40-60 percent reductions in teenage crashes during the restricted hours (Foss et al., 2001; Masten and Hagge, 2004; Mayhew, Simpson, Desmond, et al., 2003; Shope and Molnar, 2004; Ulmer et al., 2000). Studies also have found that passenger restrictions are effective in reducing crashes of teenage drivers transporting other teenagers (Chaudhary et al., 2007; Cooper et al., 2005; Masten and Hagge, 2004; Rice et al., 2004). In some jurisdictions, extending the minimum learner's permit holding period has forced license delay by at least 2-6 months. Studies in Kentucky (Agent et al., 1998), Connecticut (Ulmer et al., 2001), and Nova Scotia (Mayhew, Simpson, Desmond, et al., 2003) found substantial crash reductions from these changes.

Only a few studies have attempted to quantify the effects of graduated licensing in the United States using national crash data. Despite differences in approaches, methods, and analyses, the studies consistently reported at least some reductions related to GDL. Ferguson et al. (2007) did not examine GDL per se but observed trends in population-based fatal crash rates among teenage drivers consistent with the increasing implementation of GDL, including the increased use of passenger and nighttime restrictions. Based on analyses of state-quarter population-based fatal crash rates during 1994-2004, other researchers reported that states with three-stage graduated systems had 11 percent lower fatal crash rates for 16 year-olds and 19 percent lower injury crash rates for 16 year-olds than states without such systems (Baker et al., 2007; Chen et al., 2006). Higher reductions were identified for GDL programs with more components (e.g., nighttime restriction, minimum learner's permit holding period) compared with states with no GDL or systems with fewer components. Morrisey et al. (2006) and Dee et al. (2005) studied the relationship between teenage crash fatalities and the strength of GDL systems, based on criteria developed by IIHS. Using state-year data on fatal crashes during 1992-2002, and controlling for other factors including population, Dee et al. (2005) reported reductions of 6-10 percent in 15-17-year-old crash deaths from having a three-stage system, depending on the variables controlled for in the model. GDL systems considered good resulted in larger reductions (19 percent) than those rated fair (6 percent) or marginal (5 percent). Employing a similar approach, Morrisey et al. (2006) reported that GDL systems rated good reduced fatalities of 15-17-year-old drivers by 19 percent overall. Systems rated fair reduced fatalities of 15-17-year-olds by 13 percent, and programs rated marginal had no significant effect on young driver fatalities.

Crash Effects of Licensing Age

Graduated licensing raises the age of unrestricted driving because the intermediate license comes with restrictions. In enacting graduated licensing laws, most states did not change the statutory age when unsupervised driving (the intermediate license) may begin. Nonetheless, some effectively raised that age by introducing or increasing the minimum permit holding period. An older licensing age also can result from raising the minimum age for obtaining a learner's permit and can be an indirect consequence of placing additional restrictions on the learner's permit (e.g., minimum practice driving hours). Among US states, only New Jersey licenses at age 17; most states license at 16, 16½ or somewhere in between, and a few license younger than 16. Studies have found that licensing at 17 has resulted in lower fatal crash rates and lower injury crash rates per population in New Jersey (Ferguson et al., 1996; Williams, 2008; Williams et al., 1983).

IIHS Ratings of State Graduated Licensing Laws

To guide states in improving licensing laws for teenagers, in 2000 IIHS developed a set of optimal criteria for a three-stage graduated licensing system. The criteria were designed to assess the strength and likely effectiveness of a licensing system in reducing crashes. In particular, strong or optimal restrictions on initial unsupervised driving and how long the restrictions last were credited. In an optimal system, the learner phase begins no younger than 16 and lasts at least 6 months. Once licensed, teenagers are prohibited from driving unsupervised after 9 or 10 p.m. and prohibited from transporting more than one teenage passenger. These restrictions should remain in place for at least 1 year, preferably until age 18.

Since 2000, IIHS has used these criteria to rate the strength of state licensing laws (good, fair, marginal, poor). In 2005, a requirement that parents certify at least 30-50 hours of supervised driving in the learner phase was added to the optimal criteria. Points are assigned to key licensing components and summed to determine an overall rating (Table 1). State ratings and summaries of state teenage licensing laws are available from the IIHS website (http://www.iihs.org).

Florida is credited with implementing the first three-stage graduated licensing system in the United States, effective July 1, 1996. Since 1996, licensing requirements in most states have been strengthened substantially. Applying the current IIHS rating system to laws in effect as of the end of 1996, no state earned a good rating, two received a fair rating, nine received a marginal rating, and 39 states and the District Columbia received a poor rating. As of April 2009, 31 states and the District of Columbia have passed laws that receive a good rating, 12 states have passed laws that receive a fair rating, 7 states have passed laws that receive a marginal rating, and no state law is rated poor. No state fulfills all the criteria for an optimal system as defined by IIHS.

Study Objective

The current study builds on the preponderance of evidence that graduated licensing laws reduce teenage crashes. The purpose was to take a comprehensive look at the effects of graduated licensing laws on the fatal crashes of teenage drivers. Annual fatal crash rates per population for drivers ages 15, 16, 17, 18, and 19 during 1996-2007 are shown in Figure 1. Steady declines occurred for all age groups but were especially pronounced for 15 and 16 year-olds. The magnitudes of the percentage reductions in fatal crash rates during 1996-2007 declined with increasing age (55 percent for 15 year-olds, 50 percent for 16 year-olds, 32 percent for 17 year-olds, 23 percent for 18 year-olds, and 18 percent for 19 year-olds). Figure 1 also depicts the annual fatal crash rate for drivers ages 30-59; their rate declined by 19 percent during 1996-2007, similar to the declines experienced by 18 and 19 year-olds.

Although the national decline in fatal crash rates among teenage drivers is consistent with the increasing implementation of graduated licensing laws during 1996-2007, the current study examined more specifically the role of graduated licensing in declining fatal crash rates. The associations of the strength of state graduated licensing laws and the strength of individual graduated licensing components with fatal crash rates were evaluated.

METHODS

Approach

IIHS ratings of state GDL laws and strengths of specific components covered by the rating system were studied by examining the rate of teenage driver involvements in fatal crashes per 100,000 teenagers across variations in GDL laws. Crash rates were examined from 1996, when the first three-stage GDL law was implemented, through 2007 using Poisson regression. The corresponding fatal crash rate for drivers ages 30-59 was computed to control for state- or time-dependent influences on crash rates unrelated to graduated licensing laws such as seasonal variation, percentage of travel occurring in rural areas, vehicle mix, and economic trends. This was chosen as a comparison group because no drivers of these ages would have been subject to GDL laws during the study period. Effects of graduated licensing law components, controlling for the influence of the comparison age group, also were evaluated using Poisson regression.

Data

Data on passenger vehicle drivers involved in fatal crashes were obtained from the Fatality Analysis Reporting System (FARS), a census of fatal crashes occurring on US public roads that is maintained by the National Highway Traffic Safety Administration. For each fatal crash, FARS contains coded information describing the crash and all involved vehicles and people. Population counts by age, state, and year were obtained from the US Census Bureau and served as exposure data. Reliably recorded current and historical data on counts of licensed teenage drivers by state are not currently available (IIHS, 2006). Details of GDL laws and their effective dates during the study period 1996-2007 were summarized by IIHS staff; a summary of this information is available from the IIHS website (http://www.iihs.org).

For each of the 50 states, quarterly counts of drivers involved in fatal crashes were obtained for ages 15, 16, 17, 18, 19, 15-19, and 15-17. Population counts in each state-quarter were obtained for the same age groups by interpolation of the yearly census data; population counts were obtained as of July 1 of each year. The District of Columbia was excluded because of the very small number of fatal crashes involving teenage drivers and because many of these drivers were licensed in Virginia or Maryland and thus not licensed under the District's licensing program. GDL laws were counted as being in effect in a state-quarter if they were in effect or became effective on the first day of that quarter. Very few effective dates occurred on days that were not first days of quarters.

Graduated licensing laws in the United States are directed primarily at 16 year-olds and to a lesser extent, 15 and 17 year-olds depending on the specific components of the laws, including the licensing age. Therefore, most analyses focused on these age groups. However, older teenagers (18-19 year-olds) also may be affected in several ways. There may be an "experiential" GDL effect in which teenagers who were licensed under GDL laws would be safer drivers when they graduate to full licensure. In this scenario, a decline in the crashes of older teenagers would be expected, with the decline beginning when the first cohort of novice teenage drivers graduates to full licensure — for example, a 1-year delay for 17 year-olds if an intermediate license is available at age 16, and a 2-year delay for 18 year-olds. There also may be a "substitution effect" in which GDL restrictions may result in younger teenagers riding more frequently with older teenagers rather than driving themselves. In this scenario, GDL laws might increase the number of crashes of older teenagers as drivers, and this change would be expected to begin to occur on the effective date of the law. Males (2007) tested for a delayed effect of California's graduated licensing law on the deaths of older teenage drivers; the law was associated with significantly more deaths among 18 year-olds, which more than offset lesser declines in deaths among 16-year-old drivers. In explaining this result, Males hypothesized that older teenagers who were licensed under GDL may have had elevated crash rates, relative to older teenagers not subject to GDL restrictions, because they had not accumulated driving experience at night and with passengers. In a study of the effects of Iowa's graduated licensing law, Neyens et al. (2008) also tested a delayed effect of the law on the crashes of 18 year-olds; a nonsignificant increase was reported. The authors hypothesized that some teenagers wishing to avoid GDL restrictions delayed licensure until age 18 or 19, thereby increasing crash rates for older teenagers. In the current study, alternative analyses were conducted that tested for an immediate effect on older teenage drivers and for a delayed effect. The goal of these alternative models was not to explore fully the effects of GDL on the crash risk of older teenage drivers but to verify that there were no potentially offsetting effects of GDL for them.

Definitions and Coding of GDL Components

For the analyses of overall GDL ratings, the current IIHS rating system was applied to the laws in each state in each quarter. GDL components were coded as follows: minimum age of learner's permit and minimum age of intermediate license (number of months) (e.g., 16½ was coded as 198); minimum learner's permit holding period (number of months); minimum practice hours (number of hours); and teenage passenger restriction (maximum number of teenager passengers allowed, other than immediate family, coded as 0, 1, and 2 = no restriction or restrictions allowing 2 or more passengers). Some states phase out passenger restrictions; for example, teenagers may be prohibited from driving unsupervised with any teenage passengers for 6 months and then prohibited from driving unsupervised with one passenger for an additional 6 months. In these cases, the initial restriction (i.e., the fewest number of passengers) was coded. The code for nighttime restriction was the number of restricted hours between 8 p.m. and 5 a.m. For example, a restriction that prohibited driving between 11 p.m. and 5 a.m. was coded as 6, a restriction starting at midnight was coded as 5, and no nighttime restriction was coded as 0. Where the nighttime restriction varied by age (e.g., 11 p.m. for 16 year-olds and midnight for 17 year-olds) or by day of the week (e.g., 10 p.m. Sunday-Thursday and 11 p.m. Friday-Saturday), the earliest restriction was coded.

At least three states (Nevada, New York, and Iowa) have so-called "school licenses" that allow teenagers with learner's permits to drive unsupervised to and from school and school-sanctioned activities. The laws in these states were coded without regard to the special school licenses because the license provisions varied substantially in important respects.

The IIHS rating system does not assign points for the minimum intermediate licensing age (i.e., the minimum age at which teenagers may drive any place without supervision), but no state may receive a rating above marginal if the intermediate licensing age is younger than 16. In addition, the licensing age is addressed indirectly through granting points for a minimum learner's permit age of 16 and a minimum holding period of 6 months. In the current study, the minimum licensing age was defined as the statutory minimum age that an intermediate license can be obtained, or the minimum permit age plus the minimum permit holding period, whichever was greater.

The IIHS rating system assigns points for the duration of the nighttime restriction and points for the duration of the passenger restriction, but the durations of restrictions were not included in the models. This was partly because of the additional complexity added to an already complicated analysis. In addition, in some states the duration of a given restriction is based on the age of the teenager (e.g., the restriction lasts until age 17), and in other states the duration is based on the time elapsed since licensure (e.g., the restriction lasts for 6 months after licensure), which cannot be measured with the study data. As noted above, some states phase out restrictions, which further complicated coding the durations of these restrictions.

The analyses also did not attempt to account for the various ways GDL laws affected teenagers already in the licensing system. Some states grandfathered in teenagers who already had learner's permits and/or licenses prior to the effective date of GDL; in other states, GDL restrictions immediately applied to all teenagers of a certain age. Due to the wide variation among states and the uncertainty of how licensure practices of teenagers in a particular state were affected, this issue could not be resolved with the study data.

Poisson Regression Analysis

Quarterly fatal crash involvement counts by state were assumed to follow a Poisson distribution, a distribution in which the mean equals the variance. Poisson regression allowed the log of the mean of this distribution to vary linearly with the values of various covariates. The log of population counts, which also varied by state and by quarter, was included in the model as an offset term, which allowed results to be interpreted as rates of fatal crash involvements per population. Raising the number e to the power of a variable's parameter estimate was interpreted as the incidence rate ratio for a one-unit increase in that variable. For the categorical variables, the parameter estimate represented the incidence rate ratio for a given category relative to the reference category.

Separate models were fit for each year of age from 15 to 19, as well as for the combined age groups 15-19 and 15-17. Variation in crash rates due to state and/or time differences unrelated to GDL was controlled by including the crash rate for 30-59 year-olds as a covariate. The crash rate for this group would have been influenced by such state-time differences, but would not have been directly affected by GDL laws during the study period. The incidence rate ratio (IRR) for the comparison group ages 30-59 represents the increase or decrease in the fatal crash involvement rate per population for teenage drivers, relative to that for older drivers. Specifically, the crash rate for the comparison group predicts a 100×(IRR-1) percent increase in the teenage crash rate.

Poisson regression models evaluated the effects of the IIHS GDL rating system in predicting fatal crash rates by including the rating as a predictor. The rating of poor was taken as the reference value, with 0/1 indicator variables for marginal, acceptable, and good included in the model. This coding scheme allowed marginal, acceptable, and good ratings to be compared with a poor rating without assuming any relationship among them. In addition to the main models testing an immediate effect on 15-19 year-olds, models were constructed that tested for a delayed effect on 17, 18, and 19 year-olds. Ratings of state licensing laws during 1996-98 were derived to support analyses of effects delayed by 1, 2, and 3 years for 17, 18, and 19 year-olds, respectively.

To evaluate the association of GDL components with crash rates, Poisson regression models for each age group that included minimum permit age, minimum permit holding period, minimum practice hours, minimum licensing age, passenger restriction, and nighttime restriction were fit. Others have suggested that, because individual GDL restrictions often are introduced simultaneously in a given state, the values of these restrictions would be too correlated with each other to allow meaningful analysis of their separate effects (Baker et al., 2007; Chen et al., 2006). However, in the present study none of the pairwise correlation coefficients among studied components exceeded 0.5, suggesting that multicollinearity did not preclude analysis of individual effects with Poisson regression.

Directly controlling for state in the analyses was considered but ultimately rejected. State effect terms in the models would necessarily account for some of the variability actually due to graduated licensing laws because variation in the presence and strength of various GDL components would be expected to result in systematic variation of teen crash rates across states. With state effect variables, such variation in GDL laws would be attributed to state by state differences rather than to GDL. This is especially a concern in that a state variable would diminish or completely fail to estimate the effect of GDL laws that are present during most or all of the study period such as New York's 9 p.m. nighttime driving restriction or New Jersey's licensing age of 17.

There are similar problems with directly controlling for time in the analyses. Directly controlling for time would attribute some of the effect of GDL components to time since these components have become increasingly common throughout the study period. If GDL components are effective, then teens' fatal crash rates would be expected to decline relative to those persons unaffected by such laws. That is, time is correlated with GDL strength and the strength of the GDL components (i.e., most of the variables in the models). Further, aside from GDL, there is little reason for teens' crash rates to change over time beyond the rates of older age groups (30-59). Controlling for time by using an older age crash covariate is meaningful and should account for important factors related to time.

The comparison group of older driver crash rates was expected to account for a substantial proportion of the state-to-state and time differences by being naturally correlated to factors unrelated to GDL that affect fatal crash rates of all drivers, but its effect was estimated across all states (because it was one parameter in the model). Thus, it was less likely to attribute GDL effects to differences among states. The older driver covariate would fail to account for state or time differences only to the extent that these differences affected teen drivers in unknown different ways than older drivers.

RESULTS

Effects of Overall Strength of Graduated Licensing Laws

Table 2 lists results of the Poisson regression model estimating the effectiveness of the current IIHS GDL overall ratings in predicting teenage driver fatal crash rates during 1996-2007. The table summarizes the results of separate models for drivers ages 15, 16, 17, 18, 19, 15-19, and 15-17. All of the models assumed that the effects of GDL law changes on fatal crash rates among all teenage driver age groups began to occur in the quarter of the year in which the changes in the laws took effect. Incidence rate ratios shown in bold typeface were statistically significant ($p<0.05$).

IIHS ratings of young driver licensing laws generally lined up well with fatal crash rate reductions among teenage drivers. For 15 year-olds, laws rated good were associated with fatal crash rates 44 percent lower than laws rated poor; laws rated fair had fatal crash rates 25 percent lower. Laws considered marginal were associated with a 20 percent increase in 15 year-olds' fatal crash rates. Compared with licensing laws rated poor, laws rated good had 41 percent lower fatal crash rates for 16-year-old drivers. Fatal crash rates for 16 year-olds were 18 and 7 percent lower for laws rated fair and marginal, respectively, relative to laws rated poor. All of the estimates for 15 and 16 year-olds were statistically significant. For 17 year-olds, laws rated good were associated with significantly lower crash rates (19 percent), and laws rated marginal or fair were associated with small, nonsignificant beneficial changes, relative to laws rated poor. For 15-17 year-olds combined, fatal crash rates were 30 percent lower for laws rated good and 11 percent lower for laws rated fair compared with laws rated poor. Associations between the law ratings and fatal crash rates for 18 and 19 year-olds were small and, with one exception, not statistically significant.

Alternative Poisson regression models of the overall GDL ratings tested whether effects were delayed by 1, 2, and 3 years for 17-, 18-, and 19-year-old drivers, respectively (tables not shown). The effects of the GDL ratings on fatal crash rates for 17-year-old drivers were nearly identical to those reported in Table 2. Significant reductions in fatal crash rates of 9 percent were found for laws rated good compared with laws rated poor for 18- and 19-year-old drivers. Significant reductions in fatal crash rates for 18-year-old drivers also were found for laws rated fair (4 percent) and laws rated marginal (6 percent) relative to laws rated poor. These results are not consistent with an offsetting effect of GDL for older teenagers.

Effects of Individual Licensing Components

Analyses of the effects of individual graduated licensing components focused on drivers ages 15-17, as these are the ages targeted by graduated licensing laws. The analyses assumed that effects of GDL law changes were immediate rather than delayed for 17 year-olds. Results of the Poisson regression models for individual and combined ages 15-17 are summarized in Table 3. For predictors coded as continuous variables, the incidence rate ratio (IRR) for an n-unit increase in the parameter is equal to the value of the parameter estimate raised to the nth power. The associated percentage change is equal to $100\times(IRR^{n}-1)$ percent.

In general, results for the three age groups were similar, although the effects for 15 and 16 year-olds were somewhat stronger than those for 17 year-olds. The following summary focuses on the effects on the fatal crash rate for 15-17 year-olds combined. To aid in interpreting the findings in Table 3, percentage changes associated with illustrative changes in the GDL component values for ages 15-17 combined are presented in Table 4. The longer the licensing age was delayed, the lower the estimated fatal crash rate. A 6-month delay (e.g., from age 16 to age 16½) was associated with a 7 percent lower fatal crash rate; a delay of 1 year lowered it by 13 percent. Passenger and nighttime restrictions also were associated with significantly lower fatal crash rates. The fatal crash rate for 15-17 year-olds was 21 percent lower when novice drivers were prohibited from having any teenage passengers in their vehicles, compared with when two or more passengers were allowed. Allowing one passenger reduced the fatal crash rate for 15-17 year-olds by 7 percent. Each additional hour that novice teenage drivers were restricted from driving at night reduced the fatal crash rate. For example, nighttime restrictions beginning at 9 p.m. were associated with an estimated 18 percent reduction compared with no restriction; the reduction was 9 percent when driving was limited after 1 a.m.

With regard to permit requirements, delaying the minimum age for obtaining a learner's permit was associated with lower fatal crash rates for 15-17 year-olds combined; a 1-year delay (e.g., from age 15 to 16) reduced the fatal crash rate by 13 percent. Additional required practice hours and lengthening the minimum learner's permit holding period had little effect on the fatal crash rate, after controlling for the effects of the other licensing components. An increase in required practice hours had a very small, nonsignificant benefit on the crash rate for 15-17 year-olds combined; lengthening the minimum learner's permit holding had a negligible disbenefit.

DISCUSSION

The current study provides persuasive evidence that a strong graduated licensing law is an effective countermeasure for reducing fatal crash involvements of teenage drivers ages 15-17. Results indicate that the IIHS system for rating the strength of graduated licensing systems reflects meaningful differences between stronger and weaker systems. The ratings lined up well with reductions in fatal crash rates per population among 15-17 year-olds; the better the rating, the larger the crash rate reductions. Laws rated good were associated with a 30 percent reduction in the fatal crash rate for 15-17 year-olds compared with laws rated poor. Estimated reductions were even greater for 15 and 16 year-olds; compared with licensing laws rated poor, laws rated good had 41 percent lower fatal crash rates for 16-year-old drivers and 44 percent lower fatal crash rates for 15 year-old drivers. When graduated licensing laws first began to be enacted, there were concerns that the crashes of 15-17 year-olds would be shifted to older teenagers. The current study suggests this has not been the case. If anything, results indicate a small beneficial effect of strong laws on fatal crash rates for older teenagers.

The current study is the first to quantify the effects of the strengths of individual graduated licensing components using national fatal crash data. Fatal crash rates among 15-17 year-olds were substantially lower for laws that had strong nighttime and passenger restrictions, and the magnitudes of the reductions were reflected by the strengths of the restrictions. Notably, a restriction prohibiting any teenage passenger had a larger benefit (21 percent reduction in fatal crash rate) than a restriction allowing one teenage passenger (7 percent reduction in fatal crash rate), compared with restrictions allowing two or more passengers or no restriction. Similar significant reductions in fatal crash rates also were predicted by delays in the minimum licensing age and minimum learner's permit age; in each case, for example, a delay of 6 months resulted in a 7 percent reduction in the fatal crash rate for 15-17 year-olds. After accounting for the effects of the other licensing components, the components designed to promote more practice driving (i.e., minimum holding period and minimum practice driving hours) did not significantly affect the fatal crash rate.

Graduated licensing reflects the notion that beginners should start with an adequate amount of supervised driving in all situations and then move to unsupervised driving in low-risk situations (without too many youthful passengers and in good lighting) before graduating to unsupervised driving in all situations. The theory underlying graduated licensing is that critical experience gained at each level of licensure will reduce crash risk. As implemented in many US states, graduated licensing also has had the effect, whether intended or not, of delaying licensure; this has resulted in reduced exposure and drivers who are older, and presumably more mature, when they begin to drive unsupervised. The current study found beneficial effects associated with delaying the minimum permit age and minimum licensing age, independent of the benefits of intermediate graduated licensing restrictions. The primary intent of a minimum learner's permit holding period and minimum practice driving hours is to enhance the opportunity for beginners to gain experience in low-risk situations. It has been suggested that in some states these requirements have resulted in later licensing. Results of the current study suggest that when the effects of differences in the minimum learner's permit and licensing ages are accounted for, no further significant benefits are gained from the minimum holding period or minimum practice hours requirements.

The current study used a population-based fatal crash rate as the measure of effect. At present, there is no reliable source of state-level historical data or current information on the numbers of teenagers with learner's permits, intermediate driver's licenses, and unrestricted driver's licenses. A consequence of using population-based crash rates is that some portion of the crash rate reduction is due to delays in licensure, which reduce driving exposure and result in newly licensed drivers who are older and presumably more mature. The current study estimated the effects of delaying licensure through the minimum permit and minimum licensing ages and the effects of nighttime and passenger restrictions following licensure. Whether the effects of delayed licensure are due to the increased maturity of drivers who are older when licensed, or to decreased exposure, is unknown. The experiential effects of graduated licensing could not be fully separated.

The Poisson regression models that estimated the associations of overall ratings and the strength of individual licensing components with teenage fatal crash rates used the corresponding fatal crash rate for drivers ages 30-59 to control for state- or time-dependent influences on crash rates unrelated to graduated licensing laws. State or time variables were not included in the models as these are highly correlated with the strength of GDL components and would thus account for variability actually due to GDL. This is particularly a concern for GDL restrictions in place for all or a large part of the study period. The older age covariate is an imperfect control for state and time influences to the extent that state or time factors affected teens' fatal crash rates in some unknown respect differently than older driver crash rates were affected. The study did not establish causal relationships between the strength of GDL laws and the strength of individual GDL components and teenage fatal crash rates but rather quantified the associations of stronger GDL laws and individual components with lower teenage fatal crash rates.

In a study complementing the current one, the Highway Loss Data Institute (HLDI) evaluated how the strength of state graduated licensing laws and the strength of individual licensing components affect collision claim frequencies of young drivers per insured vehicle year (Trempel, 2009). Collision claim frequency is dominated by relatively minor crashes. Using claim frequency rates, as opposed to population-based crash rates, ensured that the subject group included only licensed drivers so that any effects are not due to reduced exposure from delays in licensure. Compared with laws rated poor, the collision claim frequency for rated drivers ages 16-17 was 15 percent lower for laws rated good, 12 percent lower for laws rated fair, and 9 percent lower for laws rated marginal. Delaying the licensing age was associated with a significant reduction in claim frequency for 16 year-olds and a nonsignificant reduction for 17 year-olds. Delaying the permit age was associated with a modest, nonsignificant reduction in claim frequency rates for both age groups. The claim frequencies of rated drivers ages 16-17 were 8 percent lower with nighttime restrictions of 9 p.m. and 5 percent lower with a restriction of zero or 1 teen passenger. There were mixed results for permit stage requirements, with a 6 percent increase in claim frequency for rated drivers ages 16-17 associated with increasing the holding period by 6 months and a 5 percent decrease associated with increasing required practice driving by 20 hours.

In summary, states with laws that include strong nighttime and passenger restrictions and states that delay the learner's permit and licensing age have fewer teenage crashes. Taken together, the current study and the HLDI study of collision claim frequencies suggest that strong graduated licensing laws are a highly effective strategy for reducing teenage crashes, including fatal crashes and less severe collisions. In addition, the findings confirm the importance of having key licensing elements: permit delay, license delay, strong nighttime restrictions, and strong teenage passenger restrictions. States that enact licensing laws with these elements can expect to achieve substantial reductions in teenage crash deaths. Apart from the effects of any associated delays in licensure, increasing the length of the holding period had little effect on fatal crashes. Licensing provisions specifically aimed at increasing the amount of practice driving did not significantly affect fatal crashes but had a modest but significant beneficial effect on less severe crashes.

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REFERENCES

Agent KR, Steenbergen L, Pigman JG, Kidd PS, McCoy C, Pollack SH. (1998) Impact of the partial graduated license program in Kentucky on teen motor vehicle crashes. In: Transportation Research Record, 1779. Transportation Research Board, Washington, DC, pp. 54-61.

Baker SP, Chen L-H, Li G. (2007) Nationwide review of graduated driver licensing. AAA Foundation for Traffic Safety, Washington, DC.

Braitman KA, Kirley BB, McCartt AT, Chaudhary NK. (2008) Crashes of novice teenage drivers: characteristics and contributing factors. J. Safety Res. 39, 47-54.

Chaudhary NK, Williams AF, Nissen W. (2007) Evaluation and compliance of passenger restrictions in a graduated driver licensing program. Report no. DOT HS-810-781. National Highway Traffic Safety Administration, Washington, DC.

Chen L-H, Baker SP, Braver ER, Li G. (2000) Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. JAMA 283, 1578-1582.

Chen L-H, Baker SP, Li G. (2006) Graduated driver licensing programs and fatal crashes of 16-year-old drivers: a national evaluation. Pediatrics 118, 56-62.

Cooper D, Gillen D, Atkins F. (2005) Measuring the impact of passenger restrictions on new teenage drivers. Accid. Anal. Prev. 37, 19-23.

Dee TS, Grabowski DC, Morrisey MA. (2005) Graduated driver licensing and teen traffic fatalities. J. Health Econ. 24, 571-589.

Doherty ST, Andrey JC, MacGregor C. (1998) The situational risks of young drivers: the influence of passengers, time of day, and day of the week on accident rates. Accid. Anal. Prev. 30, 45-52.

Ferguson SA, Leaf WA, Williams AF, Preusser DF. (1996) Differences in young driver crash involvement in states with varying licensing practices, Accid. Anal. Prev. 28, 171-180.

Ferguson SA, Teoh ER, McCartt AT. (2007) Progress in teenage crash risk during the last decade. J. Safety Res. 38, 137-45.

Fohr SA, Layde PM, Guse CE. (2005) Graduated driver licensing in Wisconsin: does it create safer drivers? Wis. Med. J. 104, 31-36.

Foss RD, Feaganes JR, Rodgman EA. (2001) Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. JAMA 286, 1588-1592.

Hallmark SL, Veneziano DA, Falb S, Pawlovich M, Witt D. (2008) Evaluation of Iowa's graduated driver's licensing program. Accid. Anal. Prev. 40, 1401-1405.

Insurance Institute for Highway Safety. (2006) Comment to the Federal Highway Administration concerning motor vehicle registration and licensed driver information; Docket no. FHWA-05-22706, March 9, 2006. Arlington, VA.

Insurance Institute for Highway Safety. (2008a) Fatality facts 2007: teenagers. Arlington, VA. Accessed at: https://www.iihs.org/research/fatality_facts_2007/teenagers.html.

Insurance Institute for Highway Safety. (2008b). [Unpublished analysis of data from US Department of Transportation's General Estimates System and National Household Travel Survey, 2001-02.] Arlington, VA.

Males M. (2007) California's graduated driver license law: effect on teenage drivers' deaths through 2005. J. Safety Res. 38, 651-659.

Masten SV, Hagge RA. (2004) Evaluation of California's graduated driver licensing program. J. Safety Res. 35, 523-535.

Mayhew DR, Simpson HM, Desmond K, Williams AF. (2003). Specific and long-term effects of Nova Scotia's graduated licensing program. Traffic Inj. Prev. 4, 91-97.

Mayhew DR, Simpson HM, Pak A. (2003) Changes in collision rates among novice drivers during the first months of driving. Accid. Anal. Prev. 35, 683-91.

McCartt AT, Shabanova VI, Leaf WA. (2003) Driving experience, crashes and teenage beginning drivers. Accid. Anal. Prev. 35, 311-20.

Morrisey MA, Grabowski DC, Dee TS, Campbell C. (2006) The strength of graduated drivers license programs and fatalities among teen drivers and passengers. Accid. Anal. Prev. 38, 135-41.

Neyens DM, Donmez B, Boyle LN. (2008) The Iowa graduated driver licensing program: effectiveness in reducing crashes of teenage drivers. J. Safety Res. 39, 383-390.

Preusser DF, Ferguson SA, Williams AF. (1998) The effect of teenage passengers on fatal crash risk of teenage drivers. Accid. Anal. Prev. 30, 217-222.

Rice TM, Peek-Asa C, Kraus JF. (2004) Effects of the California graduated driver licensing program. J. Safety Res. 35, 375-381.

Shope JT. (2007) Graduated driver licensing: review of evaluation results since 2002. J. Safety Res. 38, 165-175.

Shope JT, Molnar LJ. (2004) Michigan's graduated driver licensing program: Evaluation of the first four years. J. Safety Res. 35, 337-44.

Trempel RE. (2009) Graduated driver licensing laws and insurance collision claim frequencies of teenage drivers. Highway Loss Data Institute, Arlington, VA.

Ulmer RG, Ferguson SA, Williams AF, Preusser DF. (2001) Teenage crash reduction associated with delayed licensure in Connecticut. J. Safety Res. 32, 31-34.

Ulmer RG, Preusser DF, Williams AF, Ferguson SA, Farmer CM. (2000) Effect of Florida's graduated licensing program on the crash rate of teenage drivers. Accid. Anal. Prev. 32, 527-32.

Ulmer RG, Williams AF, Preusser DF. (1997) Crash involvements of 16-year-old drivers. J. Safety Res. 28, 97-103.

Williams AF. (2003) Teenage drivers: patterns of risk. J. Safety Res. 34, 5-15.

Williams AF. (2008) Licensing age and teenage driver crashes: a review of the evidence. Traffic Inj. Prev. 10, 9-15.

Williams AF, Ferguson SA, Wells JK. (2005) Sixteen-year-old drivers in fatal crashes in United States, 2003. Traffic Inj. Prev. 6, 202-206.

Williams AF, Karpf RS, Zador P. (1983) Variations in minimum licensing ages and fatal motor vehicle crashes. Am. J. Public Health 73, 1401-1402.

Table I
System for rating state graduated licensing systems, Insurance Institute for Highway Safety, April 2009

Learner's phase		**Points***
Minimum permit age	16 or older	1 point
	Less than 16	0 points
Permit holding period	6 or more months	2 points
	3-5 months	1 point
	Less than 3 months	0 points
Required practice hours	30 or more hours	1 point
	Less than 30 hours	0 points
Intermediate phase		**Points***
Restriction on night driving	10 pm or earlier	2 points
	After 10 pm	1 point
	No restriction	0 points
Restriction on underage passengers	Zero or 1 passenger	2 points
	2 passengers	1 point
	3 or more passengers or no restriction	0 points
Duration of night driving restriction	12 months or more from minimum licensing age	1 point
	Less than 12 months	0 points
Duration of passenger restriction	12 months or more from minimum licensing age	1 point
	Less than 12 months	0 points
Graduated licensing rating**	**Points**	
Good	6 or more points	
Fair	4-5 points	
Marginal	2-3 points	
Poor	Less than 2 points	

* Where completion of driver education changes a requirement, point values are determined for the driver education track.

** Regardless of point totals, no state is rated above marginal if intermediate licensing age is younger than 16 or if night driving and passenger restrictions are both lifted before age 16, 6 months.

Table II

Adjusted incidence rate ratios from Poisson regression analyses of the effects of GDL ratings on the rate of teenage driver fatal crashes per 100,000 teenagers, 1996-2007

	Age of teenage driver						
	15	16	17	18	19	15-19	15-17
Fatal crash rate for ages 30-59	**1.314**	**1.196**	**1.165**	**1.181**	**1.182**	**1.184**	**1.188**
GDL rating							
Good	**0.564**	**0.592**	**0.807**	0.963	0.969	**0.845**	**0.700**
Fair	**0.749**	**0.819**	0.966	1.029	1.021	**0.962**	**0.887**
Marginal	**1.195**	**0.929**	0.993	**0.957**	0.978	**0.975**	0.981
Poor	1	1	1	1	1	1	1

Note: The adjusted incidence rate ratios in bold type were statistically significant ($p<0.05$).

Table III

Adjusted incidence rate ratios from Poisson regression analyses of the effects of GDL components on the rate of teenage driver fatal crashes per 100,000 teenagers, 1996-2007

		Age of teenage driver			
		15	16	17	15-17
Fatal crash rate for 30-59 year olds		**1.209**	**1.170**	**1.166**	**1.168**
Minimum license age (months)*		**0.926**	**0.983**	1.005	**0.988**
Night restriction (number of restricted hours)*		**0.965**	**0.960**	**0.987**	**0.976**
Maximum teenage passengers permitted	0	**0.683**	**0.768**	**0.819**	**0.786**
	1	0.910	0.954	**0.932**	**0.935**
	2+	1	1	1	1
Minimum permit age (months)*		**0.950**	**0.981**	0.999	**0.989**
Minimum permit holding period (months)*		1.003	0.995	**1.007**	1.001
Minimum practice hours*		0.999	1.000	0.999	0.999

Note: The adjusted incidence rate ratios shown in bold type were statistically significant ($p<0.05$).

*The incidence rate ratio (IRR) of an n-unit increase in the predictor value is equal to the IRR for 1-unit increase raised to the nth power. This represents a percentage change of $100\times(IRR^n-1)$. For example, in the model for 15-17 year-olds, the incidence rate ratio for a 1-month increase in the minimum license age is 0.988 (1 percent reduction) and the effect of a 6-month increase is $(0.988)^6=0.930$ (7 percent reduction).

Table IV
Estimated percentage changes in rate for 15-17-year-old driver fatal crashes per 100,000 teenagers associated with specific GDL components

	Percent change
Delaying age of licensure	
1 month	**-1**
6 months	**-7**
1 year	**-13**
Restriction on teen passengers vs. no restriction or 2+ teen passengers	
None allowed	**-21**
1 allowed	**-7**
Night driving restriction	
8 p.m.	**-20**
9 p.m.	**-18**
10 p.m.	**-16**
11 p.m.	**-14**
midnight	**-12**
1 a.m.	**-9**
Delaying age of permit	
1 month	**-1**
6 months	**-7**
1 year	**-13**
Lengthening permit holding period	
1 month	0.1
3 months	0.2
6 months	0.5
Increase in minimum practice hours	
10 hours	-1
20 hours	-1

Note: The percentage changes shown in bold type were statistically significant ($p<0.05$)

Figure 1
Fatal crashes per 100,000 people among drivers ages 15, 16, 17, 18, 19, and 30-59, 1996-2007