National Evaluation of Graduated Driver Licensing Programs

Driver Fatality Rates by Age, 2004

Chart: Rate (per 100k Licensed Drivers) vs. Age (Years): 16, 17, 18, 19, 20, 21, 22, 23, 24, 25-34, 35-44, 45-54, 55-64, 65-74, >74

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16. Abstract

Context. Implementation of Graduated Driver Licensing (GDL) programs is associated with lower fatal crash rates of young drivers, but the contribution of specific components of GDL programs is not known.

Objective. To determine which types of GDL programs are associated with reductions in fatal crashes involving 16-year-old drivers.

Design, Setting, and Population. A retrospective study of involvement of 16-year-old drivers in fatal crashes in the United States from 1994 through 2004 using data obtained from the Fatality Analysis Reporting System (FARS) and the US Census Bureau. The association of various GDL programs with fatal crashes involving 16-year-old drivers was examined and compared to results for 20-24 and 25-29-year-old drivers. Analysis was based on the total number of quarters of the year in all States ("State-quarters") with or without specific GDL programs, excluding the four quarters before and the four quarters after a law was changed.

Main Outcome Measures. Incidence Rate Ratio (IRR) for fatal crashes involving 16-year-old drivers in relation to GDL programs.

Results. Overall, State-quarters having GDL programs (combined results, including weaker programs) were associated with an 11% lower [IRR 0.89, 95% confidence interval (CI) 0.80, 0.99)] fatal crash involvement rate for 16-year-old drivers, than State-quarters without GDL programs. When State-quarters without any of the seven GDL components are compared to State-quarters with GDL programs, only those programs having five or more components had significantly lower (18%-21%) fatal crash involvement rates for 16-year-old drivers. The finding that GDL is associated with lower fatal crash involvement rates is strengthened by the observation that drivers age 20 to 24 or 25 to 29 years old did not also show lower fatal crash involvement rates during comparable State quarters.

Conclusion. The most comprehensive GDL programs are associated with crash involvement rates about 20 percent lower for 16-year-olds than comparable crash involvement rates without GDL programs Based on existing programs that were sufficiently common for analysis, the greatest benefit appears to be in programs that include age requirements plus 3 or more months of waiting before the intermediate stage, nighttime driving restriction, and either supervised driving of at least 30 hours or a passenger restriction.

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EXECUTIVE SUMMARY

Background   In the United States in 2004, 16-year-old drivers were involved in 957 fatal crashes that killed 1,111 people. Graduated Driver Licensing (GDL) is an increasingly popular approach to reducing the excess risk of motor vehicle crashes for novice drivers. This study was undertaken to examine the fatal crash involvement rates of 16-year-old drivers in relation to implementation of GDL programs in the various States.

GDL allows novice drivers to build experience incrementally before they are exposed to more hazardous driving situations. The first phase of GDL is a learner's period with supervised training. This is followed by an intermediate period where unsupervised driving is limited to less hazardous situations, and a final stage without restrictions.

By the end of 2004, 41 States and the District of Columbia had GDL programs that included all three stages, although these programs vary substantially in the number and strictness of the restrictive provisions. To date, several individual GDL programs have been evaluated, and a national evaluation of GDL effectiveness has been conducted; however, a comparison of GDL programs with differing components has not previously been reported.

Approach An investigation was undertaken to:

1. assess the overall effectiveness of GDL programs across the United States in reducing fatal crashes involving 16-year-old drivers, and

2. compare the safety benefits of GDL programs with different components.

Data on fatal crashes was obtained from the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration and population data was obtained from the U.S. Census Bureau. The research analyzed the changes in fatal crash involvement rates of 16-year-old drivers in relation to the characteristics of the various GDL programs, which differ among the States. The research focused on 43 of the 48 contiguous States, using data for 1994 through 2004.

Method   Incidence Rate Ratios (IRRs) of fatal motor vehicle crashes involving 16-year-old drivers from 1994 through 2004 were calculated for each type of GDL program, adjusted for State and year. Results for 16-year-olds were compared to rates for drivers ages 20 to 24 and 25 to 29 in order to minimize the effects of time trends and changes in the driving environment and policies that were not related to GDL. Analysis was based on the total number of quarters of the year in all States ("State-quarters") with or without specific GDL programs, excluding the four quarters before and the four quarters after enactment of any program.

Results

1. When State-quarters where GDL programs were implemented are compared to State-quarters where they were not implemented, those State-quarters with GDL programs had an 11 percent lower fatal crash rate involving 16-year-olds. This lower fatal crash rate reflects the combined results for all States, some of which have relatively weak GDL requirements, and therefore underestimates the impact of stronger programs.

2. Fatal crash involvement rates of 16-year-old drivers were 18 percent lower in State-quarters with any five of the seven GDL components and 21 percent lower for State-quarters with six or seven components compared to State-quarters without any of the seven components.

3. Compared to programs without any of the seven components, fatal crash involvement rates were 16 percent to 21 percent lower in programs that included age requirements plus: 3 or more months of waiting before the intermediate stage, nighttime driving restriction, and either supervised driving of at least 30 hours or passenger restriction.

4. Drivers ages 20 to 24 or 25 to 29 years did not experience similar reductions in fatal crash involvement rates in the State-quarters with GDL programs compared to State-quarters without GDL programs. This absence of an observed effect on drivers *not exposed* to GDL increases confidence that the reductions observed in 16-year-old fatal crashes are attributable to GDL.

Conclusions

The most comprehensive GDL programs are associated with fatal crash involvement rates for 16-year-old drivers that are about 20 percent lower than programs without any of the seven GDL components. Based on existing programs that were sufficiently common for analysis, the greatest benefit appears to be associated with programs that include age requirements and:

- a waiting period of at least three months before the intermediate stage,
- a restriction on nighttime driving, and either
- 30 or more hours of supervised driving, or
- a restriction on carrying passengers.

I.   INTRODUCTION

In the United States in 2004, 16-year-old drivers were involved in 957 fatal crashes that killed 1,111 people. Sixteen-year-old drivers have an especially high risk of crash involvement. Per mile driven, their crash rate is almost 10 times the rate for drivers age 30 to 59 and more than twice the rate of 18- to 19-year-old drivers.[1] Graduated Driver Licensing (GDL) is one increasingly popular approach to managing the serious problem of high rates of fatal and nonfatal crashes among beginning drivers.

GDL allows beginning drivers to build experience incrementally before they are exposed to more hazardous driving situations. It achieves this by increasing licensing age, requiring more supervision in the initial phases of driving, and reducing exposure to high-risk situations such as carrying teen passengers and nighttime driving. The first phase of GDL is a learner's period with supervised training. This is followed by an intermediate period where unsupervised driving is limited to less hazardous situations and a final stage without restrictions. By the end of 2004, 41 States and the District of Columbia had instituted some form of GDL that included an intermediate stage.

Prior evaluation studies of GDL programs comparing rates before and after GDL implementation in individual States have reported reductions in fatal crash rates of novice drivers that ranged from 11 percent to 32 percent.[2-10] More recently, Dee et al.[11] reported a 6-percent reduction nationally in crash fatalities of 15- to 17-year-olds associated with GDL programs. The greatest reductions (19%) were in States with programs ranked "good" by the Insurance Institute for Highway Safety using a system based on the presence and strength of components considered as desirable.[11][12] However, the type of analysis used by Dee et al. does not make it possible to compare programs with different combinations of program components. Other prior evaluations have not taken advantage of the unique environment of the United States that makes it possible to compare programs among States, with attention to their specific components.

State GDL programs differ with respect to which components are included and in the specific requirements of each component, such as the required number of hours of supervised driving. However, evaluation of the individual components of GDL separately is not possible because in most States several components have been introduced or changed simultaneously, and their effects cannot be separated. Although a study of the effectiveness of individual GDL components was not possible, it is still possible to determine empirically which *types* of GDL programs are associated with the lowest fatal crash involvement rates for16-year-old drivers.

A nationwide study was therefore undertaken to assess the overall impact of GDL programs on fatal crashes of 16-year-old drivers, and to determine what *types* of GDL programs are associated with lower fatal crash involvement rates for 16-year old drivers.

The research, based on 43 of the 48 contiguous States and using data for 1994 through 2004, analyzed changes in fatal crash involvement rates of 16-year-old drivers in relation to the characteristics of the various GDL programs, which differ among the States. Appendix A presents a list of all States used in the analyses.

II. METHOD

A. Data

Data on fatal crashes and population were obtained from two Federal sources: the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration[13] and the U.S. Census Bureau.[14] FARS is a census of all fatal traffic crashes within the United States that involve a motor vehicle traveling on a public road and result in a death within 30 days of the crash. The numbers of drivers age 16 and ages 20 to 29 involved in fatal crashes in each State for each month from 1994 through 2004 were obtained from FARS. Cases where two 16-year-old drivers were involved in the same crash were counted as two events. Midyear population estimates for each State from 1994 to 2004 were obtained from the U.S. Census Bureau.

Information on GDL programs and their effective dates was obtained from the Insurance Institute for Highway Safety (IIHS),[15] State government Web sites, and personal contacts with State personnel. IIHS has been tracking GDL programs since 1996, the earliest year in which any State adopted graduated licensing programs. Three lists were obtained from IIHS: a list of components of graduated licensing programs for each State in 1996; a list including enacted, effective dates and details of licensing amendments for States that have changed their programs since 1996; and a list of components of graduated licensing programs for each State in 2005 (IIHS 2005). State government Web sites were used to confirm the programs, resolve inconsistencies, and in some cases obtain the dates of changes in the programs.

Although each GDL program has some distinct features, the main provisions in the various GDL programs generally fall into seven categories: minimum age for a learner permit; mandatory waiting period before applying for intermediate license; minimum hours of supervised driving; minimum age for intermediate license; nighttime restriction; passenger restriction; and minimum age for full licensing (Table 1). To avoid small numbers, related provisions were collapsed into dichotomous variables, for example, "nighttime driving restrictions, yes/no."

The seven components of GDL programs were coded into quarters of the year based on their effective month. For example, in Alabama unsupervised driving was prohibited from midnight to 6 a.m. beginning October 1, 2002; the first three quarters of 2002 were coded as "not exposed to the nighttime driving restriction" and the fourth quarter coded as "exposed." If a restriction became effective at any time during a quarter, that entire quarter was coded as "exposed." Quarters were used rather than calendar years because GDL programs became effective at different times of the year. The unit of analysis therefore became the State-quarter, which represents one State having a specified combination of GDL components for a given quarter of the year.

Excluded from analysis were four quarters *after* the effective date of each GDL program or component, because licensing restrictions would not affect teenagers who already had their licenses when legislation took effect. After a restriction goes into effect, it can be as long as a full year before all 16-year-old drivers in a State are driving under that restriction. Four quarters *before* the effective date were also excluded because some teenagers might hasten to get their licenses before the law changed, leading to an increased number of crashes in those quarters.

Thus a total of eight quarters were excluded from the analysis for each GDL program changed or enacted.

Table 1. Definition of Seven GDL Components Studied [1]

Minimum age for learner permit
   -   Minimum age 15 ½ years for obtaining a learner permit
   -   Reference: less than 15 ½ years

Mandatory waiting period
   -   Minimum 3 month waiting period after obtaining a learner permit before applying for an intermediate license
   -   Reference: no mandatory waiting period of at least 3 months

Minimum hours of supervised driving
   -   Minimum 30 hours of supervised driving
   -   Reference: no required supervised driving or required less than 30 hours

Minimum entry age for intermediate stage
   -   Minimum age 16 years for obtaining intermediate stage license
   -   Reference: less than 16 years

Minimum age for full licensing
   -   Minimum age 17 years for full licensing
   -   Reference: less than 17 years

Nighttime restriction
   -   Any nighttime restriction
   -   Reference: no nighttime restriction

Passenger restriction
   -   Any passenger restriction
   -   Reference: no passenger restriction

B. Analysis

We examined States that had GDL programs at any time during 1994-2004, with the objective of determining whether some programs appeared to be associated with lower fatal crash involvement rates than others. This was a cross-sectional analysis, examining the experience of 16-year-olds in each of the study years, rather than a cohort analysis, which would have followed 16-year-olds in 1994 until they were 26 years old in 2004.

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[1] The values of the specific attributes defining the components studied (shown in Table 1 above) used to distinguish weaker from stronger State GDL programs were chosen to allow large enough numbers in each category for meaningful analysis. They are *not* to be interpreted as representing ideal or even recommended GDL component attribute values, and they are not intended to provide guidance on what would be required for a State's GDL program to be considered effective. For example, while State requirements for at least 30 hours of supervised driving practice or an initial stage of at least 3 months are associated with fewer 16-year-old driver crashes, this result does not suggest that either of these is ideal. Sixty or 100 hours of supervised driving may well be preferable to 30 hours, but the available data did not allow question to be addressed. Also, the reader should be aware that there may be some excellent restrictions that do not match the seven program components that were analyzed. For example, North Carolina does not require a specified number of hours of supervised driving; rather, an intermediate license is not issued until at least a year after the initial provisional license, during which all driving must be supervised. It is possible that the impact of this provision could be even stronger that what was analyzed

The analyses included 43 States in the continental United States; of these, 36 had GDL programs for at least part of the studied period. The District of Columbia was excluded from analysis since its crash data were heavily influenced by neighboring States. Maine, New Hampshire, Rhode Island, Utah, and Virginia were excluded because they changed their laws more than twice between 1994 and 2004, thus complicating any analysis.

The number of person-years for each quarter in each State was estimated using the mid-year population of 16-year-olds divided by four. The same method was used to calculate comparison group data, i.e., person-years in each State-quarter for drivers ages 20-24 and 25-29. Within the 11-year period 1994 through 2004, 1,480 State-quarters were examined.

The association between GDL programs and fatal crash incidence was assessed using negative binomial regression models based on generalized estimating equations (GEE).[16][17] The negative binomial distribution approximates the counts of fatal crashes within State-quarters and the GEE approach takes into account the correlation among quarterly counts of fatal crashes in a given State. Statistical software SAS was used for the analysis.[18]

Independent Variables
The independent variable of primary interest was the presence or absence of GDL and its provisions. Three different approaches were used to characterize the GDL programs. In the first approach, whether a State included an intermediate phase in its licensing system was used to determine the presence or absence of GDL programs as a dichotomous variable. The reference group for this comparison was State-quarters without three-stage GDL programs. This comparison is useful because it tells you the combined effect of all GDL programs and reflects the results for all States. Some States, however, have relatively weak GDL requirements, and the results therefore underestimate the impact of stronger programs.

In the second approach, the licensing system for young drivers in each State-quarter was characterized on the basis of how many of the seven GDL components studied were contained in the licensing restrictions, regardless of which specific components are included in the count. The reference group was State-quarters that did not meet the requirements of any of the seven components that we examined. This approach made it possible to examine the impact of programs that only partially met the GDL definition. This was a simple count of components that did not depend upon the effect of each one. It addressed the question, "How many components are needed in order to have an effective program?"

The third approach helped to identify the specific components of a good GDL program. As with the second approach, categorization of programs was based solely on their components, without considering whether the programs included an intermediate phase that would have qualified them as GDL programs. Again, the reference group was State-quarters that did not meet the requirements of any of the seven components. In this approach, the licensing systems for young drivers were grouped based on combinations of the four GDL program components not related to age of licensing: minimum waiting period of at least three months before applying for an intermediate license, minimum supervised driving of 30 hours, any nighttime restriction, and any passenger restriction. One program grouping, for example, included all State-quarters with a combination of a waiting period of at least three months, a nighttime driving restriction and a passenger-carrying restriction. Programs with only age restrictions were treated as a separate category. If a program grouping existed in fewer than 50 State-quarters then it was not treated as

a separate category but was combined with other groupings that occurred too infrequently for separate analysis.

Three models based on the three approaches described above were fitted for each of the three age groups studied: drivers age 16, 20 to 24, and 25 to 29. The focus of our study was on 16-year-old drivers. However, fatal-crash-involved drivers ages 20 to 24 and 25 to 29 were also analyzed to allow comparison between GDL-exposed and non-GDL-exposed drivers. Theoretically, GDL programs will not affect the older age groups and therefore their Incidence Rate Ratios (IRRs) should be equal to one.

Dependent Variable
The outcome variable was the natural logarithm (the unit used for all negative binomial models) of the number of fatal crashes involving any drivers in our target age groups in a given State-quarter. States and quarters as dummy variables and year as a continuous variable were included in each model. The State variables controlled for State-specific unmeasured variations that might affect fatal crash counts, such as weather, traffic environment, regulations other than GDL, and socioeconomic conditions. The quarter variables controlled seasonal variations and the year variable controlled for variation in fatal crash counts over the time period studied. The sum of person-years in each State-quarter was considered as exposure and was included in each model.

Fatal crash involvement rates of drivers were used rather than driver fatality rates because they allowed more cases to be included for study. Person-years based on the population of 16-year-olds were used because the licensing rate might have changed due to implementation of GDL programs. Also, the overall benefit to the population, regardless of the licensing rate, was of primary interest.

III. RESULTS

From 1994 to 2004, 8,953 16-year-old drivers were involved in fatal crashes in the 43 States examined; 64 percent of the drivers were male and 36 percent were female. During this 11-year period, one-third (34%) of all fatal crashes involving 16-year-old drivers occurred in State-quarters in which GDL programs had been implemented (Table 2). The restrictions in effect for the smallest proportion of State-quarters were a requirement of at least 30 hours of supervised driving (19% of State-quarters) and restrictions related to carrying passengers (15%).

With adjustment for changes over time and differences among States that were unrelated to GDL, implementation of GDL programs was associated with an overall 11 percent lower fatal crash involvement rate for 16-year-old drivers [Incidence Rate Ratio (IRR) 0.89, 95% CI 0.80, 0.99] when compared to fatal crash involvement rates in States without GDL programs. This overall difference is based upon comparison of fatal crash involvement rates for State-quarters with and State-quarters without GDL programs. The difference reflects the combined results for all States, some of which have relatively weak GDL requirements, and therefore underestimates the impact of stronger programs. There was no significant change for drivers aged 20-24 (IRR 0.97, 95% CI 0.92, 1.03) and 25-29 (IRR 0.99, 95% CI 0.93, 1.05).

Table 2. Percentages of State-Quarters With Specified GDL Restrictions, and 16-Year-Old Drivers Involved in Fatal Crashes in Relation to GDL Programs in the United States, 1994-2004.

|	Categories	No. (%) of States[2]	No. (%) of State-quarters (Total 1,480)		N (%) of 16-year-old drivers (Total 8,953)		Rates[3]
GDL programs	Yes	36 (84)	507	(34)	3,230	(36)	25
	No	7 (16)	973	(66)	5,723	(64)	32
Minimum age for learner	15 ½ yrs	13 (30)	517	(35)	2,761	(31)	22
	<15 yrs 6 months	30 (70)	963	(65)	6,192	(69)	35
Mandatory waiting period	3+ months	37 (86)	663	(45)	3,946	(44)	27
	None or <3 months	6 (14)	817	(55)	5,007	(56)	31
Minimum of supervised Driving	30+ hours	18 (42)	285	(19)	1,775	(20)	24
	None or <30 hours	25 (58)	1,195	(81)	7,178	(80)	31
Minimum age intermediate Stage	16+ years	29 (67)	458	(31)	3,164	(35)	23
	None or <16 years	14 (33)	1,022	(69)	5,789	(65)	35
Minimum age full licensing	17+ years	23 (53)	492	(33)	3,273	(37)	22
	< 17 years	20 (47)	988	(67)	5,680	(63)	37
Nighttime restriction	Any	31 (72)	581	(39)	3,820	(43)	23
	None	12 (28)	899	(61)	5,133	(57)	36
Passenger restriction	Any	21 (49)	221	(15)	1,198	(13)	21
	None	22 (51)	1,259	(85)	7,755	(87)	31
Total			1,480	(100)	8,953	(100)	29

[2] As of 2004, for the 43 States studied.
[3] Driver fatal crash involvement rate – the number of crashes per 100,000 person-years for relevant State-quarters.

The relationship between the fatal crash involvement rate and the total number of GDL program components is shown in Figure 1. State-quarters with and without any of the seven specified GDL components were compared.

Only GDL programs (during State-quarters) with five or more components had significantly lower fatal crash involvement rates for 16-year-old drivers compared to State-quarters without GDL programs. This difference for 16-year-old drivers was 18 percent for programs with five components and 21 percent for those with six or seven components.

Figure 1. Percent Change in Annual Fatal Crash Involvement Rate in Relation to Number of GDL Program Components, Compared to State-Quarters With None of the Seven Components in Table 1, for Drivers Age 16, 20-24, and 25-29; United States, 1994-2004. Vertical Lines Represent 95-Percent Confidence Limits.
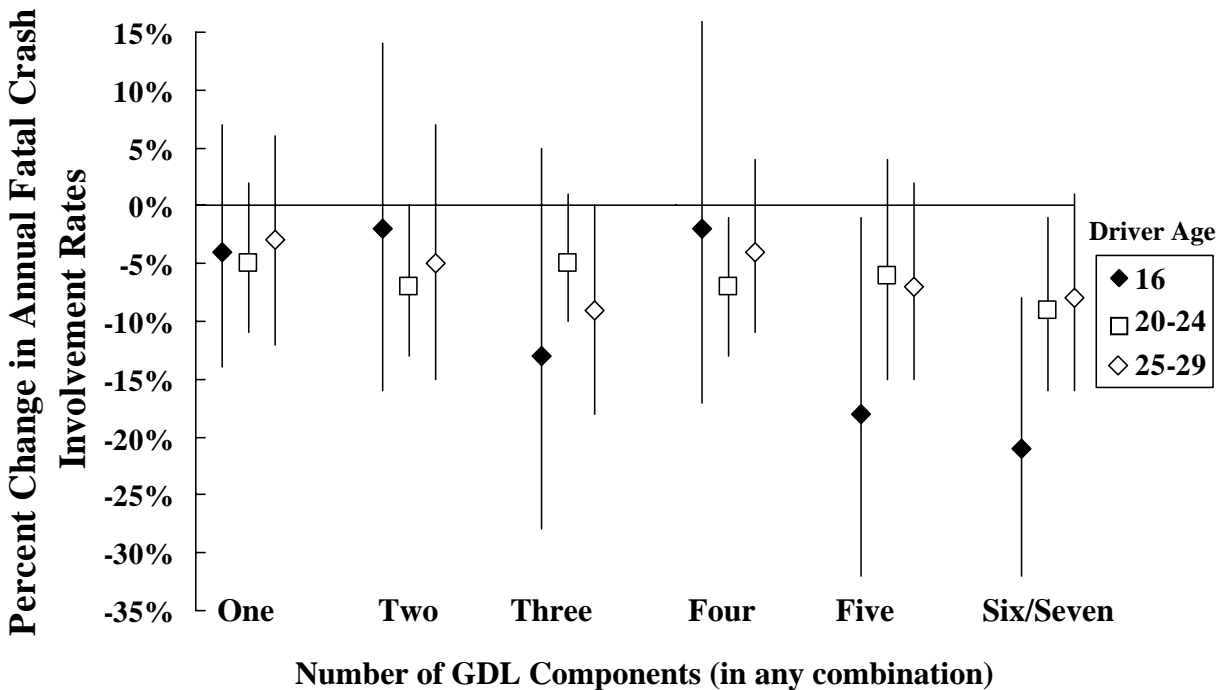
The lower fatal crash involvement rates associated with novice licensing systems varied with the provisions included in the laws. Compared to State-quarters with none of the seven specified GDL components, State-quarters with only age restrictions did not show an association with a significantly lower rate of fatal crashes involving 16-year-old drivers. This is shown in Table 3 below.

GDL programs B through H with various combinations of four major components (other than age components) were also compared to State-quarters having none of the seven GDL program components. Significantly lower rates (16-21%) in fatal crashes involving 16-year-old drivers were associated only with three types of GDL programs, all of which contained a minimum waiting period of at least three months after obtaining a learner permit and a nighttime restriction, plus either:

- passenger restrictions, 21-percent reduction (IRR 0.79, 95% CI 0.66, 0.94); or
- 30 hours of supervised driving in the learner period, 18-percent reduction (IRR 0.82, 95% CI 0.71, 0.95); or
- both, 16-percent reduction (IRR 0.84, 95% CI 0.74, 0.96).

These GDL-associated lower fatal crash involvement rates of 16-year-old drivers were not seen for drivers ages 20 to 24 and 25 to 29, who were not affected by GDL. The percent changes for these three types of programs did not differ significantly from one another.

Table 3. Incident Rate Ratios (IRRs) and 95-Percent Confidence Intervals (CIs) for Fatal Crashes Involving 16-Year-Old Drivers in Relation to GDL Program Components, Excluding Age Requirements, Compared to Older Drivers in the Same States. United States, 1994-2004.

Program	Components				# State-quarters	IRRs (95% CIs)		
	Learner 3+ months	Supervised 30+ hrs	Nighttime restriction	Passenger restriction		Age 16	Age 20-24	Age 25-29
A[1]					186	0.95(0.85-1.08)	0.94(0.87-1.02)	0.96(0.87-1.06)
B			Yes		143	0.96(0.83-1.11)	0.94(0.89-1.00)	0.91(0.82-1.01)
C	Yes				184	1.01(0.87-1.16)	0.97(0.91-1.04)	0.99(0.89-1.11)
D	Yes		Yes		99	0.96(0.81-1.14)	0.97(0.89-1.05)	0.98(0.90-1.06)
E[2]	Yes		Yes	Yes	95	0.79(0.66-0.94)	1.00(0.91-1.09)	0.97(0.89-1.07)
F[2]	Yes	Yes	Yes		141	0.82(0.71-0.95)	0.92(0.86-1.00)	0.94(0.86-1.02)
G[2]	Yes	Yes	Yes	Yes	83	0.84(0.74-0.96)	0.93(0.85-1.01)	0.93(0.84-1.02)
H[3]	Other combinations of components					1.07(0.85-1.36)	0.89(0.82-0.96)	0.94(0.84-1.05)
Reference[4]	No	No	No	No	468			

[1]Programs having age restrictions but none of these four components.
[2]Confidence limits for age 16 do not include 1.
[3]Programs with too few State-quarters for analysis.
[4]State-quarters with none of the seven components in Table 1, which included three age-related restrictions as well as the four restrictions in this table.

Reading Table 3: Program type F, for example, has three components and was in effect in 141 State-quarters. Sixteen-year-old drivers exposed to Program F were 18-percent lower (i.e., 1-0.82) in those 141 GDL State-quarters, compared to State-quarters with none of the seven components in Table 1. For drivers ages 20 to 24 and 25 to 29 the differences were only 8 percent and 6 percent, respectively, (comparing their fatal crash involvement rates in those 141 quarters with fatal crash involvement rates in State-quarters with none of the seven components) and were not statistically significant since the confidence intervals included 1.

IV. DISCUSSION

A. National Differences in Fatal Crash Involvement Rates

Results of this research provide a national overview of the association between various GDL programs and fatal crash involvement rates of 16-year-old drivers – the drivers most affected by GDL implementation. Adjusting for differences over time and among States, the most comprehensive GDL programs were associated with fatal crash involvement rates for 16-year-old drivers, that were about 20 percent lower than programs without any of the seven GDL components. For all full GDL programs combined, implementation was associated with an 11-percent lower fatal crash involvement rate for 16-year-old drivers compared to State-quarters without GDL. This overall difference reflects the combined results for all three-stage GDL programs. Including States with relatively weak programs dilutes the effect; even so, 11 percent is a substantial and important overall difference.

Other investigators interested in crashes of teenage drivers have taken different approaches to assessing progress. Williams and colleagues,[19] analyzing the trend in per capita fatal crash rates of 16-year-old drivers in the United States between 1993 and 2003, without regard for GDL implementation, reported a 26-percent drop during this decade. The finding by Dee and colleagues [11] of a reduction of only 6 percent associated with GDL programs may underestimate the effectiveness of GDL in reducing fatalities because 16- and 17-year-old drivers were affected very differently by GDL programs. This may be a smaller reduction than would have been found specifically for 16-year-olds, due to combining results for 16- and 17-year-old drivers. Moreover, the authors did not exclude results for the four quarters after GDL restrictions took effect, and given that GDL programs do not impact 16-year-olds already licensed, their finding may underestimate the effect. Shope and Molnar [5] pointed out that in the first year following implementation the law applied to only about two-thirds of the 16-year-old drivers.

Our analyses showed that programs having fewer than five of the seven major components (including programs that did not qualify for three-stage GDL programs) were not associated with significant differences in fatal crash rates of 16-year-old drivers when compared to State-quarters with none of the seven components, while a difference of 18-21 percent was associated with programs having at least five components. This result is similar to the 19-percent lower rate reported for programs meeting the IIHS criteria for 'good' programs.[11 12]

B. Comparing Specific Programs

Unlike most other countries, in the United States GDL programs vary among States. This offers a special opportunity for comparing the impact of GDL programs with different combinations of restrictions. This is the first time that analysis of the association between fatal crash involvement rates and GDL programs with specific groups of components has been reported. Our analysis of programs with specified groupings of components (without considering age criteria) revealed that programs that included a mandatory waiting period of at least three months before the intermediate phase, a requirement of 30 or more hours of supervised driving, and passenger and nighttime driving restrictions were associated with fatal crash involvement rates for 16-year-old drivers that were 16 to 21 percent lower when, compared to programs with none of the seven components in Table 1. Drivers ages 20 to 24 and 25 to 29 did not experience significant changes in fatal crash involvement rates, suggesting that the lower fatal crash involvement rates for 16-year-old drivers were independent of non-GDL changes in policies or the driving environment that affected all drivers. GDL programs with only age criteria were not associated with reductions in fatal crash involvement rates.

According to Williams and Ferguson,[20] the effectiveness of GDL programs in reducing crash risk depends upon addressing both age and inexperience. They suggested three mechanisms underlying the safety benefit of GDL programs: raising the licensing age, increasing the length of the low-risk supervised learner period,[21] and reducing high-risk driving after initial licensure. Research on individual States suggests that the minimum age components are associated with crash reductions because they delay age of full licensure and therefore reduce 16-year-old drivers' exposure to driving. For example, Shope et al.[3] found a substantial reduction in the number of 16-year-olds obtaining licenses after Michigan adopted a GDL program. It is clear that part of the safety benefit of GDL is due to reduced exposure to driving,[22] which by itself can be expected to lead to reduced crashes and injuries.[23] Our analysis of the number of components of driver licensing systems also suggested that age of licensure is important. Indeed, without age components a program would not have five or more components, the number needed to make a significant difference. In addition, of course, the age components delay licensure, which is important because it can reduce exposure of 16-year-olds.

Our analysis indicates that GDL components intended to reduce high-risk driving at night or with teenage passengers after initial licensure contribute to the effectiveness of GDL programs. It is not possible to discern whether the association we observed is directly due to enforcement of the nighttime driving and passenger restrictions, or whether parent-imposed limits on high-risk driving of 16-year-olds are stricter in States with more restrictive programs. The importance of parental involvement cannot be overestimated, and Simons-Morton states that future reductions in teen driver crashes may depend upon increasing parental management.[23] Hartos and colleagues [24] reported that parents appear better able to establish and enforce teenage driving restrictions when State laws support them. Whatever the mechanism by which nighttime and passenger restrictions are associated with lower crash rates, a program with those components is clearly advantageous.

C. Limitations

In the absence of data on age-specific driver populations and time spent in driving, we were unable to determine the extent to which GDL-associated changes in fatal crashes involving 16-year-old drivers were due to reduced exposure associated with decreased licensure or to decreased driving time and distance.

Also, it was not possible to determine whether a law was effective due to enforcement or to public support and other factors affecting compliance with the law. When a particular GDL program is not associated with a lower crash rate, it is likely that compliance is low and this could be due to flaws in the policy or to the environment of the policy, such as publicity, enforcement, and parental involvement. Some restrictions are easier to enforce than others. Requirement of a 3- or 6-month waiting period is virtually always enforced because it is an integral part of how the licensing system functions, rather than depending upon the actions of tens of thousands of individual parents, while certified supervised driving will largely depend on the willingness and ability of parents to supervise. A night driving restriction is far easier for parents to enforce than a passenger restriction. Goodwin and Foss[25] surveyed teenagers and their parents in North Carolina and confirmed that violation of restrictions without parental knowledge was more common for passenger restrictions than nighttime restrictions.

Another limitation was that some groups of GDL components were present in too few State-quarters for analysis, which could have prevented identification of successful programs. For example, it is possible that a program with only nighttime and passenger restrictions would have been effective, but there were too few State-quarters when such programs were in effect to test this hypothesis. Also, small numbers made it impossible to use more detailed categories for GDL components. For example, we were not able to determine whether results varied with the number of passengers allowed or the permitted age for supervisors. Previous studies have indicated that crash risk of teenage drivers increased with the number of passengers.[26][27] The importance of supervisor age is underscored by data from Chen et al.,[27] who found the highest case-fatality rates of 16-year-old drivers in crashes when passengers age 20 to 29 were present. This might be related to the fact that older passengers may legally buy alcohol and (illegally) provide it to underage drinkers, although Rice et al.[28] indicated that the presence of adults age 20 to 29 was associated with severe or fatal injury among 16- and 17-year-old drivers even when alcohol use was controlled. Williams and Shabanova [29] reported that teen drivers were less likely to use safety belts when passengers were in their twenties, and recommended that passenger restrictions not be waived unless there is a supervisor at least 30 years old. This recommendation is reasonable because mature passengers are more likely to take some responsibility for the safety of a trip.

Finally, our findings may underestimate the benefit of GDL because we assumed that a restriction imposed at any time during a three-month period became effective at the beginning of the period. Any effect of this assumption is likely to be small because most restrictions do, in fact, become effective at the beginning of a calendar quarter, and because the analysis excluded data for the entire year following the effective date of each GDL requirement.

V. CONCLUSION

GDL programs as a whole are associated with substantially lower fatal crash involvement rates for 16-year-old drivers. The most comprehensive programs appeared to be associated with the greatest benefit. That benefit amounted to about a 20-percent-lower fatal crash involvement rate**,** (comparing State-quarters having comprehensive GDL programs to those without GDL programs), and it suggests that effective GDL programs need to be comprehensive.

Among existing programs that were sufficiently common for analysis, significantly lower fatal crash involvement rates for 16-year old drivers were associated with programs having five or more components, including age requirements and:

- a waiting period of at least three months before the intermediate stage,
- a restriction on nighttime driving, and either
- 30 or more hours of supervised driving, or
- a restriction on carrying passengers.

Public health agencies, members of the public, and physicians can play a useful role by working to achieve comprehensive GDL programs and encouraging parents of beginning drivers to enforce GDL requirements.

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Appendix: List of All States Used in the Analyses*

State	GDL Effective Date
Alabama	10/1/2002
Arizona	None
Arkansas	7/1/2002
California	7/1/1998
Colorado	7/1/1999
Connecticut	10/1/2003
Delaware	7/1/1999
Florida	7/1/1996
Georgia	7/1/1997
Idaho	1/1/2001
Illinois	1/1/1998
Indiana	1/1/1999
Iowa	1/1/1999
Kansas	None
Kentucky	None
Louisiana	1/1/1998
Maryland	7/1/1999
Massachusetts	11/4/1998
Michigan	4/1/1997
Minnesota	1/1/1999
Mississippi	7/1/2000
Missouri	1/1/2001
Montana	None
Nebraska	1/1/1999
Nevada	7/1/2001
New Jersey	1/1/2001
New Mexico	1/1/2000
New York	9/1/2003
North Carolina	12/1/1997
North Dakota	None
Ohio	1/1/1999
Oklahoma	None
Oregon	3/1/2000
Pennsylvania	12/22/1999
South Carolina	7/1/1998
South Dakota	1/1/1999
Tennessee	7/1/2001
Texas	1/1/2002
Vermont	7/1/2000
Washington	7/1/2001
West Virginia	1/1/2001
Wisconsin	7/1/2000
Wyoming	None

*The District of Columbia was excluded from analysis since its crash data was heavily influenced by neighboring States. Maine, New Hampshire, Rhode Island, Utah, and Virginia were excluded because they changed their laws more than twice between 1994 and 2004. Alaska and Hawaii were also not included in the analyses.

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