ARTICLE

Graduated Driver Licensing Programs and Fatal Crashes of 16-Year-Old Drivers: A National Evaluation

Li-Hui Chen, MS, PhD[a], Susan P. Baker, MPH[a], Guohua Li, MD, DrPH[b]

[a]Center for Injury Research and Policy, Johns Hopkins University, Bloomberg School of Public Health, Baltimore, Maryland; [b]Department of Emergency Medicine, Johns Hopkins University, School of Medicine, Baltimore, Maryland

The authors have indicated they have no financial relationships relevant to this article to disclose.

ABSTRACT

CONTEXT. Implementation of graduated driver licensing programs is associated with reductions in crash rates of young drivers, but graduated driver licensing programs vary in their components. The impact of programs with different components is unknown.

OBJECTIVE. The purpose of this work was to determine which graduated driver licensing programs are associated with the greatest reductions in fatal motor vehicle crashes involving 16-year-old drivers.

METHODS. We conducted a retrospective study of all 16-year-old drivers involved in fatal crashes in the United States from 1994 through 2004 using data from the Fatality Analysis Reporting System and the US Census Bureau. We measured incidence rate ratios of fatal motor vehicle crashes involving 16-year-old drivers according to graduated driver licensing programs, adjusted for state and year.

RESULTS. Compared with state quarters with no graduated driver licensing program components, reductions of 16% to 21% in fatal crash involvement rates of 16-year-old drivers occurred with programs that included ≥3-month mandatory waiting period, nighttime driving restriction, and either ≥30 hours of supervised driving or passenger restriction. Reductions of 18% to 21% occurred in state quarters with programs that included ≥5 of the 7 components examined. Drivers aged 20 to 24 or 25 to 29 years did not experience significant reductions.

CONCLUSION. Comprehensive graduated driver licensing programs are associated with reductions of ~20% in 16-year-old drivers' fatal crash involvement rates. The greatest benefit seems to be associated with programs that include age requirements and ≥3 months of waiting before the intermediate stage, nighttime driving restriction, and either ≥30 hours of supervised driving or passenger restriction.

www.pediatrics.org/cgi/doi/10.1542/peds.2005-2281

doi:10.1542/peds.2005-2281

Dr Chen's current address is National Center for Health Statistics, 3311 Toledo Rd, Hyattsville, MD 20782

Key Words
graduated driver licensing programs, injury prevention and control, 16-year-old drivers, evaluation, fatal crashes

Abbreviations
GDL—graduated driver licensing
FARS—Fatality Analysis Reporting System
IRR—incidence rate ratio
CI—confidence interval

Accepted for publication Jan 19, 2006

Address correspondence to Susan P Baker, MPH, Center for Injury Research and Policy, Johns Hopkins University, Bloomberg School of Public Health, 624 North Broadway, Baltimore MD 21205-1996. E-mail: sbaker@jhsph.edu

In the United States, 16-year-old drivers were involved in 957 fatal crashes in 2004 that killed 1111 people. Sixteen-year-old drivers have an especially high risk of crash involvement. Per mile driven, their crash rate is ~10 times the rate for drivers aged 30 to 59 years and more than twice the rate of 18- to 19-year-old drivers.[1] Graduated driver licensing (GDL) is an increasingly popular approach to 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, 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.

Evaluations of GDL programs comparing rates before and after GDL implementation in individual states have reported reductions in crash rates of novice drivers that ranged from 11% to 32%.[2–10] However, previous 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. Recently, Dee et al[11] reported a 6% 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] The type of analysis used by Dee et al[11] does not make it possible to compare programs with different combinations of program 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. Evaluation of the separate components of GDL is not possible, because in most states, several components have been introduced or changed simultaneously, making it impossible to separate their effects. Therefore, a nationwide study was undertaken to assess the overall impact of GDL on fatal crashes of 16-year-old drivers and to determine empirically which types of GDL programs are associated with the greatest reduction in crashes of 16-year-old drivers.

METHODS

Data

Data on fatal crashes and population were obtained from 2 federal sources: the Fatality Analysis Reporting System (FARS) of the National Highway Traffic Safety Administration[13] and the US 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 aged 16 and aged 20 to 29 years 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 2 events. Midyear population estimates for each state from 1994 to 2004 were obtained from the US Census Bureau. Information on GDL programs and their effective dates was obtained from the Insurance Institute for Highway Safety,[15] state government Web sites, and personal contacts with state personnel.

Although each GDL program has some distinct features, the main provisions in the various GDL programs generally fall into 7 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 7 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 AM beginning October 1, 2002; the first 3 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

TABLE 1 Definition of GDL Components Examined

Minimum age for learner permit
Minimum age 15.5 years for obtaining a learner permit
Reference: <15.5 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 or <3 months
Minimum hours of supervised driving
Minimum 30 hours of supervised driving
Reference: no required supervised driving or required <30 hours
Minimum entry age for intermediate stage
Minimum age 16 years for obtaining intermediate stage license
Reference: <16 years
Minimum age for full licensing
Minimum age 17 years for full licensing
Reference: <17 years
Nighttime restriction
Any nighttime restriction
Reference: no nighttime restriction
Passenger restriction
Any passenger restriction
Reference: no passenger restriction

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 1 state having a specified GDL component for a given quarter.

Excluded from analysis were 4 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.

The analyses included 43 states in the continental United States; 36 had GDL programs for at least part of the studied period. Washington DC was excluded from analysis, because 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 midyear population of 16-year-olds divided by 4. The same method was used to calculate exposure data, that is, person-years in each state quarter for 20- to 24-year-old and 25- to 29-year-old drivers. Within the 11-year period 1994 through 2004, 1480 state quarters were examined.

Analysis

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

Dependent Variable

The outcome variable was the natural logarithm (the unit used for all of the 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 of drivers was used rather than driver fatalities, because it 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 because of implementation of GDL programs. Also, the overall benefit to the population, regardless of the licensing rate, was of primary interest.

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 3-stage GDL programs.

The second and third approaches focused on the 7 GDL components studied. The programs were categorized solely based on their components, without considering whether the programs included an intermediate phase. This made it possible to examine the impact of programs that only partially met the GDL definition, thereby helping to identify the components of a good GDL program.

In the second approach, the licensing system for young drivers in each state quarter was characterized on the basis of how many of the 7 GDL components studied were contained in the licensing restrictions. The reference group was state quarters that did not meet the requirements of any of the 7 components that we examined.

In the third approach, the licensing systems for young drivers were grouped based on combinations of the 4 GDL program components not related to age of licensing: minimum waiting period of 3 months before applying for an intermediate license, minimum supervised driving of 30 hours, any nighttime restrictions, and any passenger restrictions; programs with only age restrictions were treated as an independent category. If a program grouping existed in <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. Again, the reference group was state quarters that did not meet the requirements of any of the 7 components.

Three models based on the 3 approaches described above were fitted for each of the 3 age groups studied: drivers aged 16, 20 to 24, and 25 to 29 years. The focus of our study was 16-year-old drivers. Fatal crash-involved drivers aged 20 to 24 and 25 to 29 years were analyzed for comparison. Theoretically, GDL programs

will not affect the older age groups, and, therefore, their incidence rate ratios (IRRs) should be equal to 1.

RESULTS

From 1994 to 2004, 8953 sixteen-year-old drivers were involved in fatal crashes in the 43 states examined; 64% of the drivers were males, and 36% were females. 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 ≥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% reduction in fatal crashes involving 16-year-old drivers (IRR: 0.89; 95% confidence interval [CI]: 0.80–0.99). This overall reduction is based on comparison of crash rates for state quarters with and without GDL programs. The reduction reflects the combined results for all of the 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 to 24 (IRR: 0.97; 95% CI: 0.92–1.03) and 25 to 29 (IRR: 0.99; 95% CI: 0.93–1.05).

The relationship between the fatal crash involvement rate and the total number of GDL program components is shown in Fig 1. State quarters with and without any of the 7 specified GDL components were compared. Only programs with ≥5 components in the corresponding state quarters experienced a significant reduction in fatal crash involvement of 16-year-old drivers and also showed reductions that differed from those of drivers in their twenties. The reductions for 16-year-old drivers were 18% for programs with 5 components and 21% for those with 6 or 7 components.

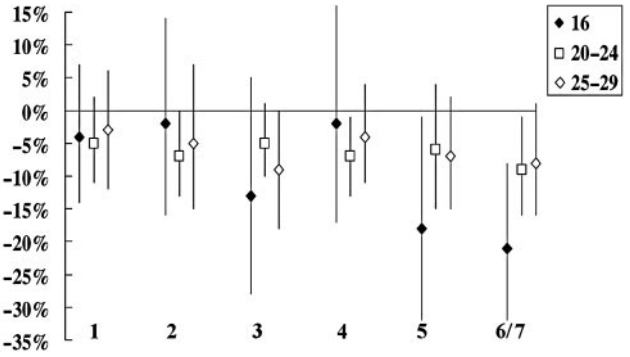

FIGURE 1
Percent change and 95% CIs in fatal crash rate in relation to driver age and number of GDL program components, compared with state quarters with none of the 7 components in Table 1, 1994–2004.

The reduction in fatal crash involvement rates associated with novice licensing systems varied with the provisions included in the laws. Compared with state quarters with none of the 7 specified GDL components, state quarters with only age restrictions did not show an association with a significantly reduced number of fatal crashes involving 16-year-old drivers (Table 3). GDL programs B through H with various combinations of 4 major components (other than age components) were also compared with state quarters having none of the 7 GDL program components. Significant reductions of 16% to 21% in fatal crashes involving 16-year-old drivers were associated only with GDL programs that con-

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

Variable	Categories	No. (%) of States[a]	No. (%) of State Quarters (Total 1480)		No. (%) of 16-Year-Old Drivers (Total 8953)		Rates[b]
GDL programs	Yes	36 (84)	507	(34)	3230	(36)	25
	No	7 (16)	973	(66)	5723	(64)	32
Minimum age for learner permit	15 y, 6 mo	13 (30)	517	(35)	2761	(31)	22
	<15 y, 6 mo	30 (70)	963	(65)	6192	(69)	35
Mandator waiting period	≥3 mo	37 (86)	663	(45)	3946	(44)	27
	None or ≤3	6 (14)	817	(55)	5007	(56)	31
Minimum hour of supervised driving	≥30 h	18 (42)	285	(19)	1775	(20)	24
	None or <30	25 (58)	1195	(81)	7178	(80)	31
Minimum age for intermediate stage	≥16 y	29 (67)	458	(31)	3164	(35)	23
	None or <16 y	14 (33)	1022	(69)	5789	(65)	35
Minimum age for full licensing	≥17 y	23 (53)	492	(33)	3273	(37)	22
	<17 y	20 (47)	988	(67)	5680	(63)	37
Nighttime restriction	Any	31 (72)	581	(39)	3820	(43)	23
	None	12 (28)	899	(61)	5133	(57)	36
Passenger restriction	Any	21 (49)	221	(15)	1198	(13)	21
	None	22 (51)	1259	(85)	7755	(87)	31
Total			1480	(100)	8953	(100)	29

[a] Driver fatal crash involvement rate per 100 000 person-years for relevant state quarters.
[b] Through 2004, for the 43 states studied.

TABLE 3 **IRRs and 95% CIs for Fatal Crashes Involving 16-Year-Old Drivers in Relation to GDL Program Components, Excluding Age Requirements, Compared With Older Drivers in the Same States, United States, 1994–2004**

Program	Components				No. State Quarters	IRRs (95% CIs)		
	Learner ≥3 mo	Supervised ≥30 h	Nighttime Restriction	Passenger Restriction		Age 16 y	Age 20–24 y	Age 25–29 y
A[a]					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[b]	Yes		Yes	Yes	95	0.79 (0.66–0.94)	1.00 (0.91–1.09)	0.97 (0.89–1.07)
F[b]	Yes	Yes	Yes		141	0.82 (0.71–0.95)	0.92 (0.86–1.00)	0.94 (0.86–1.02)
G[b]	Yes	Yes	Yes	Yes	83	0.84 (0.74–0.96)	0.93 (0.85–1.01)	0.93 (0.84–1.02)
H[c]	Other combinations of components					1.07 (0.85–1.36)	0.89 (0.82–0.96)	0.94 (0.84–1.05)
Reference[d]	No	No	No	No	468			

[a] Programs having age restrictions but none of these 4 components.
[b] Confidence limits for ages 20 to 24 and 25 to 29 years do not include IRR for age 16 years.
[c] Programs with too few state quarters for analysis.
[d] State quarters with none of the 7 components in Table 1.

tained a minimum waiting period of ≥3 months after obtaining a learner permit and a nighttime restriction, plus: (1) passenger restrictions (21% reduction [IRR: 0.79; 95% CI: 0.66–0.94]); or (2) 30 hours of supervised driving in the learner period (18% reduction [IRR: 0.82; 95% CI: 0.71–0.95]); or (3) both (16% reduction [IRR: 0.84; 95% CI: 0.74–0.96]).

These GDL-associated reductions in fatal crashes of 16-year-old drivers were not seen for drivers aged 20 to 24 and 25 to 29 years, who were not affected by GDL. The percentage of reductions for these 3 types of programs did not differ significantly from one another.

DISCUSSION

National Reductions

Results of this research provide a national overview of the association between various GDL programs and fatal crashes of 16-year-old drivers, the drivers most affected by GDL implementation. The most comprehensive programs were associated with reductions of ~20% in crash rates of 16-year-old drivers, adjusted for differences over time and among states. For all of the full GDL programs combined, implementation was associated with an 11% reduction in fatal crashes involving 16-year-old drivers when compared with state quarters without GDL. This overall reduction reflects the combined results for all of the 3-stage GDL programs. Including states with relatively weak programs dilutes the reduction; even so, 11% is a substantial and important overall reduction.

Other investigators interested in crashes of teenage drivers have taken different approaches to assessing progress. Williams et al,[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% drop during this decade. The finding by Dee et al[11] of a reduction of only 6% 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; combining results for 16- and 17-year-old drivers may have shown a smaller reduction than would have been found specifically for 16-year-olds. Also, they did not exclude results for the 4 quarters after GDL restrictions took effect. Shope and Molnar[5] pointed out that in the first year after implementation, the law applied to only about two thirds of the 16-year-old drivers.

Our analyses showed that programs having <5 of the 7 major components (including programs that did not qualify for 3-stage GDL programs) were not associated with significant reductions in fatal crash rates of 16-year-old drivers when compared with state quarters with none of the 7 components, whereas a reduction of 18% to 21% was associated with programs having ≥5 components. This result is similar to the 19% reduction reported for programs meeting the Insurance Institute for Highway Safety criteria for good programs.[11,12]

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 combinations that included a mandatory waiting period of ≥3 months before the intermediate phase, a nighttime driving restriction, and either ≥30 hours of supervised driving or a passenger restriction were associated with reductions of 16% to 21% in fatal crashes of 16-year-old drivers. Drivers aged 20 to 24 or 25 to 29 years did not experi-

ence significant reductions in fatal crash involvement rates, suggesting that the reductions in fatal crashes of 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 crash rates.

According to Williams and Ferguson,[20] the effectiveness of GDL programs in reducing crash risk depends on addressing both age and inexperience. They suggested 3 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 because of 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, because without age components, a program would not have ≥5 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 that we observed is directly because of 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 et al[23] state that future reductions in teen driver crashes may depend on increasing parental management. Hartos et al[24] reported that parents seem 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 crash reductions, a program with those components seems to be desirable.

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 reductions in fatal crashes involving 16-year-old drivers were because of reduced exposure associated with decreased licensure or because of decreased driving time and distance.

Also, it was not possible to distinguish the benefits of a law, per se, from benefits of implementation, enforcement, and compliance with that law. When a particular GDL program is not associated with a reduction in crash involvement, it is likely that compliance is low, and this could be because of flaws in the policy or 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 on the actions of tens of thousands of individual parents, whereas 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. 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 aged 20 to 29 years 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 aged 20 to 29 was associated with severe or fatal injury among 16- and 17-year-old drivers even when alcohol use was controlled for. Williams and Shabanova[29] reported that teen drivers were less likely to use seat belts when passengers were in their 20s, and recommended that passenger restrictions not be waived unless there is a supervisor ≥30 years of age. This recommendation is reasonable, because mature passengers are more likely to take some responsibility for the safety of a trip.

Finally, our estimates may underestimate the benefit of GDL, because we assumed that a restriction imposed at any time during a 3-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 after the effective date of each GDL requirement.

CONCLUSIONS

GDL programs as a whole are associated with substantial reductions in 16-year-old drivers' fatal crash involvement rates. The most comprehensive programs seemed to be associated with the greatest benefit (~20% reduction, comparing state quarters with and without GDL programs or specified GDL components), suggesting that effective GDL programs need to be comprehensive. Among existing programs that were sufficiently common for analysis, significant reductions were associated with programs having ≥5 components, including age requirements and ≥3 months of waiting before the intermediate stage, nighttime driving restriction, and either ≥30 hours of supervised driving or restriction on carrying passengers. Pediatricians and family physicians can play a role by working with legislators to achieve comprehensive GDL programs and by encouraging parents of beginning drivers to enforce GDL requirements.

ACKNOWLEDGMENTS

This research was funded by the National Highway Traffic Safety Administration under a cooperative agreement with the Johns Hopkins University (DTNA22-03-H-05123) and in part by the Center for Injury Research and Prevention, Centers for Disease Control and Prevention (grant CCR302486). Paul J. Tremont, PhD, was the National Highway Traffic Safety Administration project officer for this study.

REFERENCES

1. Williams AF. Teenage drivers: patterns of risk. *J Safety Res.* 2003;34:5–15
2. McKnight AJ, Peck RC. Graduated driver licensing: what works? *Inj Prev.* 2002;8(suppl 2):ii32–ii38
3. Shope JT, Molnar LJ, Elliott MR, Waller PF. Graduated driver licensing in Michigan: early impact on motor vehicle crashes among 16-year-old drivers. *JAMA*. 2001;286:1593–1598
4. Shope JT, Molnar LJ. Graduated driver licensing in the United States: evaluation results from the early programs. *J Safety Res.* 2003;34:63–69
5. Shope JT, Molnar LJ. Michigan's graduated driver licensing program: evaluation of the first four years. *J Safety Res.* 2004; 35:337–344
6. Foss RD, Feaganes JR, Rodgman EA. Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina. *JAMA*. 2001;286:1588–1592
7. Cooper D, Atkins F, Gillen D. Measuring the impact of passenger restrictions on new teenage drivers. *Accid Anal Prev.* 2005; 37:19–23
8. Hedlund J, Compton R. Graduated driver licensing research in 2004 and 2005. *Accid Anal Prev.* 2005;36:108–119
9. Hedlund J, Compton R. Graduated driver licensing research in 2003 and beyond. *J Safety Res.* 2004;35:5–11
10. Simpson HM. The evolution and effectiveness of graduated licensing. *J Safety Res.* 2003;34:25–34
11. Dee TS, Grabowski DC, Morrisey MA. Graduated driver licensing and teen traffic fatalities. *J Health Econ.* 2005;24:571–589
12. Morrisey M, Grabowski D, Dee T, Campbell C. The strength of graduated drivers license programs and fatalities among teen drivers and passengers. *Accid Anal Prev.* 2006;36:135–141
13. National Highway Traffic Safety Administration. Fatality analysis reporting system (FARS) web-based encyclopedia. Available at: www-fars.nhtsa.dot.gov. Accessed March 15, 2005
14. US Census Bureau. US Census Bureau, population estimates, entire data set. Available at: www.census.gov/popest/datasets.html. Accessed March 15, 2005
15. Insurance Institute for Highway Safety. US licensing systems for young drivers. Available at: www.iihs.org/safety_facts/state_laws/us_licensing_systems.pdf. Accessed April 10, 2005
16. Diggle P, Heagerty P, Liang K-Y, Zeger S. *Analysis of Longitudinal Data*. 2nd ed. New York, NY: Oxford University Press; 2002
17. Hardin J, Hilbe J. *Generalized Estimating Equations*. Boca Raton, FL: Chapman & Hall/CRC; 2003
18. SAS Institute Inc. *The SAS System for Windows* [computer program]. Version 9.1. Cary, NC: SAS Institute Inc; 2003
19. Williams A, Ferguson S, Wells J. Sixteen-year-old drivers in fatal crashes, United States, 2003. *Traffic Inj Prev.* 2005;6: 202–206
20. Williams AF, SA. Rationale for graduated licensing and the risks it should address. *Inj Prev.* 2002;8(suppl 2):ii9–ii16
21. Mayhew DR, Simpson HM, Pak A. Changes in collision rates among novice drivers during the first months of driving. *Accid Anal Prev.* 2003;3:683–691
22. Hedlund J, Shults RA, Compton R. What we know, what we don't know, and what we need to know about graduated driver licensing. *J Safety Res.* 2003;34:107–115
23. Simons-Morton BG, Hartos JL, Beck KH. The persistence of effects of a brief intervention on parental restrictions of teen driver privileges. *Inj Prev.* 2003;9:142–146
24. Hartos JL, Simons-Morton BG, Beck KH, Leaf WA. Parent-imposed limits on high-risk adolescent driving: are they stricter with graduated driver licensing? *Accid Anal Prev.* 2005;37: 557–562
25. Goodwin AH, Foss RD. Graduated driver licensing restrictions: awareness, compliance, and enforcement in North Carolina. *J Safety Res.* 2004;35:367–374
26. Preusser DF, Ferguson SA, Williams AF. The effect of teenage passengers on the fatal crash risk of teenage drivers. *Accid Anal Prev.* 1998;30:217–222
27. Chen LH, Baker SP, Braver ER, Li G. Carrying passengers as a risk factor for crashes fatal to 16- and 17-year-old drivers. *JAMA*. 2000;283:1578–1582
28. Rice TM, Peek-Asa C, Kraus JF. Nighttime driving, passenger transport, and injury crash rates of young drivers. *Inj Prev.* 2003;9:245–250
29. Williams AF, Shabanova VI. Responsibility of drivers, by age and gender, for motor-vehicle crash deaths. *J Safety Res.* 2003; 34:527–531

Graduated Driver Licensing Programs and Fatal Crashes of 16-Year-Old Drivers: A National Evaluation

Li-Hui Chen, Susan P. Baker and Guohua Li

Pediatrics 2006;118;56
DOI: 10.1542/peds.2005-2281

Graduated Driver Licensing Programs and Fatal Crashes of 16-Year-Old Drivers: A National Evaluation

Li-Hui Chen, Susan P. Baker and Guohua Li

Pediatrics 2006;118;56
DOI: 10.1542/peds.2005-2281