Initial Effects of Graduated Driver Licensing on 16-Year-Old Driver Crashes in North Carolina

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Motor vehicle crashes are the most common cause of death among teenagers in the United States. In 1998, 38% of deaths from all causes among teens 15 to 19 years of age resulted from motor vehicle crashes. The bulk of the teen driver problem is concentrated among the youngest drivers. Among 16-year-old drivers, the crash rate per mile driven is 43% greater than for 17-year-olds, 2.7 times greater than for 18-year-olds, and 3.9 times that of 19- and 20-year-old drivers. Moreover, while motor vehicle death rates per licensed driver among all drivers older than 17 years declined from 1976 to 1996, reflecting the effects of a variety of safety improvements, the per driver death rate among 16-year-olds increased considerably.

The greater crash propensity among novice drivers results from a combination of simple lack of driving experience and impulsive behaviors characteristic of youth. To address the high crash risk among the youngest beginning drivers, 34 states and the District of Columbia have implemented graduated driver licensing (GDL) systems, all within the past 4 years. Graduated driver licensing programs are designed to provide young beginning drivers with substantial practical driving experience under the safest possible conditions, moving drivers through 2 levels with limited driving privileges before full licensure. This article presents findings from an initial investigation of the effects of the North Carolina GDL program on 16-year-old driver crashes.

Context Since 1997, 32 states have enacted graduated driver licensing (GDL) systems to reduce crash rates among young novice drivers.

Objective To determine the initial effect of the North Carolina GDL system on crashes among 16-year-old drivers.

Design, Setting, and Subjects Comparison of population-based North Carolina motor vehicle crash rates before (1996-1997) and after (1999) 16-year-old drivers were licensed under the GDL system. To control for other factors that might have influenced crashes, changes for 16-year-old drivers were compared with those of drivers 25 to 54 years of age. Crashes per licensed driver were also examined.

Intervention The North Carolina GDL system, enacted December 1, 1997, requires beginning drivers 15 to 17 years of age to hold level 1 licenses, allowing driving only while supervised by a designated adult for a full year; followed by level 2 licensure, allowing unsupervised driving from 5 AM to 9 PM and supervised driving at any time for at least 6 months; and, finally, level 3—a full, unrestricted license.

Main Outcome Measures Rates of motor vehicle crashes among 16-year-old drivers in 1996-1997 vs 1999, overall and by crash severity (fatal, injury, and noninjury), time (night vs day), type (single vs multiple vehicle), driver alcohol use, and driving environment (more vs less rural counties).

Results Crash rates declined sharply for all levels of severity among 16-year-old drivers after the GDL program was implemented. Following GDL, 16-year-old driver crashes were substantially less likely. Comparing 1996 with 1999, fatal crashes declined 57%, from 5 to 2 per 10000 population (rate ratio [RR], 0.43; 95% confidence interval [CI], 0.27-0.70); crashes with no or minor injuries decreased 23%, from 1068 to 826 per 10000 (RR, 0.77; 95% CI, 0.75-0.80). Nighttime crashes were 43% less likely (156 vs 88 per 10000; RR, 0.57; 95% CI, 0.52-0.61) and daytime crashes decreased by 20% (951 vs 764 per 10000; RR, 0.80; 95% CI, 0.78-0.83). Single-vehicle crashes (245 vs 175; RR, 0.71; 95% CI, 0.67-0.76) declined somewhat more than multiple-vehicle crashes (866 vs 681; RR, 0.79; 95% CI, 0.76-0.81).

Conclusion In its initial years, the North Carolina GDL system produced substantial declines in 16-year-old driver crashes.

JAMA. 2001;286:1588-1592  
www.jama.com
Before enactment of GDL in North Carolina, persons 15 years or older who had passed a mandatory driver education class, a vision test, a sign recognition test, and a written driving test could begin driving if supervised; persons 16 years or older could begin with no supervision and with no practice besides that obtained during driver education. The North Carolina GDL system, enacted December 1, 1997, requires beginning drivers who are at least 15 years old and younger than 18 years to hold level 1 licenses, which allow driving only while supervised by a designated adult for a full year. After completing the final 6 months of level 1 licensure with no traffic violations and passing a road test, a driver may move to level 2 licensure, which allows unsupervised driving from 5 AM to 9 PM and supervised driving at any time. On completion of at least 6 continuous months at this level with no traffic violations, drivers graduate to a full, unrestricted license.

New drivers must be at least 15 years of age to begin, at least 16 years to move to level 2, and at least 16½ years to move to level 3. Progression is time and achievement based rather than a direct function of age. Thus, the North Carolina GDL system changed the licensing process substantially, instituting a mandatory period of practice embodied in 2 preliminary licensing levels. Both these levels involve constraints on driving to ensure that early driving occurs under relatively safe conditions. Additionally, young beginning drivers now must earn the privilege of an unrestricted license by demonstrating safe driving behaviors during the first 18 months of licensure. Previously, an unrestricted license could be achieved merely by passing tests.

Analyses focused first on all crashes, then on subcategories based on severity (fatal, serious injury, or minor or no injury), time (day vs night), type (single vs multiple vehicle), alcohol involvement, and driving environment (more vs less urban counties). To measure urbanization, counties were ranked by the proportion of the population residing in a municipality of 2500 or more population, then divided into quartiles. Crash severity was classified based on police officer reports of injury to occupants and reflects the most severe injury to any occupant involved in the crash. In North Carolina, injuries are coded as fatal, incapacitating injury, visible minor injury, possible injury (complaint of pain with no visible injury), or no injury (property damage only). Results for minor or possible injury and property damage crashes were similar and are combined for presentation. To compute rates, midyear population estimates for North Carolina were obtained from the US Census Bureau Web site (http://www.census.gov/population/www/estimates/st-99-10.html). Driver license information was extracted from the North Carolina Driver History File.

Examination of the effects of GDL systems typically involves a number of complications that are not usually present when evaluating other traffic safety policies or programs. The most important of these in North Carolina are the following. First, following implementation of GDL, 18 months passed before a single driver could have progressed to the third, essentially unrestricted, licensing level. Second, persons who obtained a learner permit before December 1, 1997, were exempt from the new licensing system. Third, there was an increase in licensing among young drivers during the last few months of 1997 because teens rushed to become licensed before GDL took effect, possibly rendering 1997 crash data somewhat problematic as a baseline. Finally, since young drivers do not all begin the licensing process at the same time or the same age, in the beginning years of a GDL program, there is inevitably a mixture of license levels in an age cohort.

Few 16-year-old drivers in 1998 had been licensed under the GDL system, and none of those licensed under GDL had progressed beyond the first level of the licensing process. For the analyses reported herein, we compared 16-year-old driver crash data for December 1, 1998, through November 30, 1999 (hereafter referred to as 1999) with those from 1996 and 1997 (December 1, 1995, through November 30, 1997). Although there were 16-year-old drivers in 1999 who had been licensed without experiencing GDL provisions, they would have had at least a year of driving experience by December 1, 1998, approximating the experience of those licensed under GDL.

To facilitate comparisons with studies of other GDL systems, we conducted analyses similar to those used in other North American jurisdictions.\(^{9-11}\) Crash rates based on age-specific populations were computed to adjust for population growth from 1996 to 1999. To control for general crash trends that might reflect economic factors, special traffic safety initiatives, or varying levels of enforcement, changes in 16-year-old driver crash rates were compared with those for drivers 25 to 54 years of age.

We conducted Poisson regression analyses to test for the predicted decrease in crash involvement for 16-year-old drivers. That is, the number of crashes is assumed to follow a Poisson distribution, and the canonical link function that relates the linear predictor to the expected number of crashes is the natural logarithm.\(^{12}\) As is common in this type of analysis, the natural logarithm of the midyear age-specific population, or the number of licensed drivers, was incorporated into the analysis as an “offset.” This serves to normalize the fitted cell means to a per person or per driver basis, since the total number of crashes, not individual drivers’ crash experience, is observed.\(^{13}\) The regression equation included classification variables for the year the crash occurred (1996, 1997, and 1999) and the age group of the driver (16 years and 25-54 years). The rate ratios (RRs) reported herein are exponentiated linear combinations of the regression parameter estimates. The confidence
EFFECTS OF GRADUATED DRIVER LICENSING

Table. Crash Rates for 16-Year-Old Drivers, per 10,000 Population, Before and After Implementation of the North Carolina Graduated Driver Licensing System

<table>
<thead>
<tr>
<th>Severity</th>
<th>1996</th>
<th>1997</th>
<th>1999</th>
<th>RR (95% CI)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All crashes</td>
<td>1111</td>
<td>1181</td>
<td>855</td>
<td>0.77 (0.75-0.79)</td>
<td>0.72 (0.70-0.74)</td>
</tr>
<tr>
<td>Injury</td>
<td>37</td>
<td>40</td>
<td>27</td>
<td>0.72 (0.62-0.84)</td>
<td>0.68 (0.59-0.79)</td>
</tr>
<tr>
<td>Minor/no injury</td>
<td>1068</td>
<td>1136</td>
<td>826</td>
<td>0.77 (0.75-0.80)</td>
<td>0.73 (0.71-0.75)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Time</th>
<th>1996</th>
<th>1997</th>
<th>1999</th>
<th>RR (95% CI)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daytime (5 AM-8:59 PM)</td>
<td>951</td>
<td>1012</td>
<td>764</td>
<td>0.80 (0.78-0.83)</td>
<td>0.76 (0.73-0.78)</td>
</tr>
<tr>
<td>Nighttime (9 PM-4:59 AM)</td>
<td>156</td>
<td>165</td>
<td>88</td>
<td>0.57 (0.52-0.61)</td>
<td>0.53 (0.49-0.58)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>1996</th>
<th>1997</th>
<th>1999</th>
<th>RR (95% CI)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single vehicle</td>
<td>245</td>
<td>257</td>
<td>175</td>
<td>0.71 (0.67-0.76)</td>
<td>0.68 (0.64-0.72)</td>
</tr>
<tr>
<td>Multiple vehicle</td>
<td>866</td>
<td>925</td>
<td>681</td>
<td>0.79 (0.76-0.81)</td>
<td>0.74 (0.71-0.76)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>1996</th>
<th>1997</th>
<th>1999</th>
<th>RR (95% CI)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver drinking</td>
<td>1090</td>
<td>1157</td>
<td>837</td>
<td>0.77 (0.75-0.79)</td>
<td>0.72 (0.70-0.74)</td>
</tr>
<tr>
<td>Driver not drinking</td>
<td>866</td>
<td>925</td>
<td>681</td>
<td>0.79 (0.76-0.81)</td>
<td>0.74 (0.71-0.76)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Urban-rural quartiles</th>
<th>1996</th>
<th>1997</th>
<th>1999</th>
<th>RR (95% CI)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>First (most urban)</td>
<td>1174</td>
<td>1259</td>
<td>908</td>
<td>0.77 (0.74-0.80)</td>
<td>0.72 (0.70-0.75)</td>
</tr>
<tr>
<td>Second</td>
<td>1086</td>
<td>1131</td>
<td>841</td>
<td>0.77 (0.73-0.82)</td>
<td>0.74 (0.70-0.79)</td>
</tr>
<tr>
<td>Third</td>
<td>1047</td>
<td>1117</td>
<td>791</td>
<td>0.76 (0.70-0.81)</td>
<td>0.71 (0.66-0.76)</td>
</tr>
<tr>
<td>Fourth (most rural)</td>
<td>857</td>
<td>947</td>
<td>672</td>
<td>0.76 (0.68-0.85)</td>
<td>0.71 (0.64-0.79)</td>
</tr>
</tbody>
</table>


RESULTS

The Table displays crash rates per 10,000 population and RRs for various types of crashes, comparing crash rates for 1999 vs 1996 and 1997 separately. Overall crash rates for 16-year-olds increased slightly from 1111 (per 10,000 population) in 1996 to 1181 in 1997, then declined substantially, following implementation of GDL, to 855 in 1999. Sixteen-year-olds were 23% less likely to experience a crash in 1999 than in 1996 (1999 vs 1996: RR, 0.77; 95% CI, 0.75-0.79).

 LICENSING among 16-year-olds declined only slightly from 1996 (63%) to 1999 (61%). However, compared with 1996 and 1997, in 1999 the level of license held by 16-year-old drivers was much more heterogeneous, reflecting a greater variety of conditions under which they were permitted to drive. Some would have been driving with no restrictions; others were limited to driving only during the daytime if unsupervised; still others were allowed to drive only while supervised by a parent or guardian, regardless of time of day. Hence, the 1996 and 1997 crash rates based on licensed drivers are not directly comparable with those in 1999. Crash rates per 10,000 licensed drivers declined 19%, from 1757 in 1996 to 1415 in 1999 (1999 vs 1996: RR, 0.81; 95% CI, 0.78-0.83). Findings from analyses of various crash types per licensed driver parallel those for population-based rates in the Table, but show a somewhat lesser decrease in crash rates. Because the heterogeneity of license types in 1999 renders a comparison of driver-based rates to earlier years difficult to interpret, we report only the population-based rates for analyses of subgroups of crash types.

Although all crashes are of concern, there is a special interest in reducing the most serious crashes, those that kill or injure. As the Table shows, 16-year-old driver fatal crash involvement was reduced by more than half in 1999 compared with either 1996 or 1997, whereas involvement in nonfatal injury crashes declined by 28% to 32% and noninjury crashes decreased by 23% to 27%. Single-vehicle crashes declined somewhat more than multiple-vehicle crashes. Crashes where the young driver was drinking were rare, and although they appear to have declined more than nondrinking crashes, the difference is not statistically significant. Finally, although driving conditions differ substantially between densely populated urban areas and more rural areas, crash rates declined similarly regardless of population density.

Effect of the Night Driving Restriction

The benefit of the nighttime driving restriction, which lasts only 6 months for most young drivers, is evident. Compared with 1996, 16-year-old driver crashes between 9 PM and 5 AM in 1999 were 43% less likely, whereas daytime crashes declined by 20%.

Adjusting for Overall Crash Trends

We controlled for changes in population by examining population-based crash rates. To some extent, possible changes in exposure to crashes were controlled by examining crashes per licensed driver. It is also important to consider whether the observed decrease in 16-year-old driver crashes may have been due to a general trend in crash likelihood rather than to the GDL program. Following an approach used by others,9,10 we compared 16-year-old crash rates with those for an older age group (25-54 years) that would not have been affected by GDL, but would have been influenced by other factors that may have affected crash rates or crash severity. Among this older age group, crashes increased by 9.7% from 1996 to 1999; adjusted for population changes, the increase was 3.6%. With the exception of alcohol-related crashes, population-adjusted rates for the older age group increased in every crash subgroup as well, indicating that the decreases among 16-year-old drivers did not result from a general downward trend in crashes. Adjusting for the overall crash trend, the crash rate among 16-year-olds decreased 27% (1999 vs 1996, adjusted: RR, 0.73; 95% CI, 0.71-0.75) from 1996 to 1999.

COMMENT

The results of the current study clearly indicate that the North Carolina GDL

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system is having the intended benefit. Both population-based and driver-based crash rates have declined markedly among the age group directly affected by GDL. Moreover, there is evidence that at least one of the specific elements of the GDL system is having the intended effect as well. As a result of the night driving restriction, crashes during the hours when young driver crash risks are highest have declined more, even though this restriction applies to most drivers for only 6 months. Most of this reduction is likely the result of less driving during this high-risk time, which the restriction is designed to achieve.

Like the GDL systems in New Zealand and Nova Scotia, the North Carolina system goes further toward implementing the central concept of GDL—providing for more practice under reduced risk conditions—than many of the other early GDL programs in the United States. All GDL systems involve an initial stage wherein risk is minimized by the requirement of an adult supervisor. North Carolina’s initial stage lasts longer than in most states, and the supervisor is expected to be an adult with an explicit responsibility to the young driver (eg, a parent or guardian), not merely an older licensed driver as is typical elsewhere.

During the second stage of GDL, driving risk is typically minimized by a prohibition of unsupervised driving under the highest-risk conditions. The first GDL programs in the United States implemented this by limiting unsupervised driving during late night hours. Recently, several states have included a restriction on the number of young passengers as well. Although the risk of 16-year-old driver crashes increases beginning by 10 PM and most night driving in this age group occurs before midnight, most GDL programs only prohibit unsupervised driving after midnight. By contrast, the North Carolina GDL system, along with 3 other states, begins the night driving restriction by 9 PM, thereby more effectively implementing the principle of reduced exposure to high-risk driving for inexperienced 16-year-old drivers.

Some caution in interpreting the results presented herein is in order. First, initial declines following enactment of GDL programs reflect the combined effects of several factors. Some of these are inherent in GDL, whereas others reflect transient conditions associated with introduction of GDL. The post-GDL (1999) cohort we examined may have included a greater proportion of persons driving under protective restrictions during part of the year than will be the case in future years. Although more than 3 years have passed since the North Carolina GDL program was implemented, these findings represent early returns. They demonstrate real declines in crash rates, but it is not yet clear whether the magnitude of effect reported herein will continue. The New Zealand GDL program, which has been in place long enough for researchers to monitor enduring effects, produced initial crash reductions similar to those reported herein, but the long-term benefit has been a sustained decrease of 7% to 8% in crash-related injuries among teen drivers.

A second reason for caution is that during the initial years of GDL, there is a reduction in various kinds of driving exposure compared with pre-GDL driving, which probably results in fewer crashes. Young drivers may drive less, fewer may be driving at all, and many more are driving under safer conditions (eg, with parents, only during daylight hours, or both). The decline in driver-based crash rates suggests that the decrease is not simply due to a delay in licensure or permanent. Nonetheless, it is not currently known how much exposure is altered or how much of the change in exposure for beginning teen drivers is temporary and how much is permanent. Consequently, only after North Carolina and other states move beyond the initial, transitional years of GDL will the enduring benefits of the program become apparent.

As a final caution, it should be recognized that GDL programs that are structured differently may produce different results than we found for North Carolina. Although it appears reasonable to assume that a comprehensive GDL program will effect a decrease in crashes among young beginning drivers, declines of the magnitude reported herein should not be expected from programs that differ notably from the North Carolina GDL system.

Further research will be necessary to fully understand the relative contributions of different components of GDL programs and to disaggregate the benefits of reduced high-risk exposure and improved driving. It will be necessary to have (1) crash data for a longer time period, (2) more detailed information about the relative distribution of various license types in the age cohort under consideration, and (3) information about the amount of driving actually done by young drivers. We are currently collecting these data and will be able to more clearly separate the component effects of the North Carolina GDL program in the future. Determining the benefits of the North Carolina GDL system for 17- and 18-year-old drivers who began driving under the GDL program, future analyses will also be able to address more clearly the extent to which GDL reduces crashes by producing safer drivers, independent of the benefits that result from the reduced exposure of young drivers to high-risk conditions.

Even if the entire effect of GDL programs is due to a reduction in driving under risky conditions, resulting from restrictions on beginning drivers, the benefit of substantially reducing crashes in this very high-risk group is considerable. In North Carolina, during 1999 alone, the result was dozens of lives preserved, thousands of injuries prevented, and millions of dollars saved as a result of the substantial reduction in crashes among 16-year-old drivers. Although much of this benefit may have been achieved by altering driving conditions for beginning drivers, it does not appear to have resulted simply from delaying licensure or increasing the driving age.

Finally, in view of the clear benefits of GDL demonstrated in North Carolina and elsewhere, in those states

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(Reprinted) JAMA, October 3, 2001—Vol 286, No. 13 1591
that currently have no GDL system or where there is a relatively weak GDL pro-
gram, physicians should consider advising both their teen patients and par-
ents of teens to follow the principles of a model GDL program. This should in-
clude at least 6 months during which the teen drives extensively with a respon-
sible adult supervisor, followed by prohibitions on unsupervised nighttime driving and transporting of passengers, until the teen has accumulated at least 6 months of additional driving experience without an adult supervisor.18–20

Author Contributions: Study concept and design: Foss. Analysis and interpretation of data: Foss, Feaganes, Rodgman.
Drafting of the manuscript: Foss. Critical revision of the manuscript for important intellectual content: Foss, Feaganes, Rodgman.
Statistical expertise: Feaganes.
Obtained funding: Foss. Administrative, technical, or material support: Foss, Rodgman.

Funding/Support: This project was supported in part by the National Highway Traffic Safety Administration under cooperative agreement DTH22-94-H15148 and the North Carolina Governor’s Highway Safety Program.

Disclaimer: The opinions, findings, and recommenda-
tions contained herein are those of the authors and do not necessarily represent those of the National Highway Traffic Safety Administration or the North Carolina Governor’s Highway Safety Program.

Acknowledgment: We express appreciation to Bill Tolbert, MA, and Carol Martell, BA, for assistance with data management and analysis and to Donald Reinfurt, PhD, for comments on a draft of the manuscript.

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