

# The Effect of Extending Graduated Driver Licensing to Older Novice Drivers in Indiana

October 2019

## **Title**

---

The Effect of Extending Graduated Driver Licensing to Older Novice Drivers in Indiana

*(October 2019)*

## **Authors**

---

Yudan Chen Wang, Robert D. Foss, & Arthur H. Goodwin  
*University of North Carolina Highway Safety Research Center*

Allison E. Curry  
*Children's Hospital of Philadelphia & University of Pennsylvania Perelman School of Medicine*

## Foreword

---

Graduated Driver Licensing systems were designed to help young novice drivers learn to drive in relatively safe environments, and then grant them more privileges and responsibilities as they gain more experience. These systems have been proven to reduce crash rates and save lives of young novice drivers. Historically, most U.S. states have applied these licensing systems only to new drivers younger than 18 years of age. However, research by the AAA Foundation for Traffic Safety has found that one in three drivers receives his or her first license at the age of 18 or older.

This report investigates the results of one state's expansion of several key components of its Graduated Driver Licensing system to all new drivers younger than 21 years of age. The work described in this report should be of interest to researchers who evaluate the impacts of traffic safety policies, as well as to practitioners responsible for training or licensing new drivers.

C. Y. David Yang, Ph.D.

Executive Director  
AAA Foundation for Traffic Safety

## About the Sponsor

---

AAA Foundation for Traffic Safety  
607 14<sup>th</sup> Street, NW, Suite 201  
Washington, D.C. 20005  
202-638-5944  
[www.aaafoundation.org](http://www.aaafoundation.org)

Founded in 1947, the AAA Foundation for Traffic Safety in Washington, D.C., is a nonprofit, publicly supported charitable research and education organization dedicated to saving lives by preventing traffic crashes and reducing injuries when crashes occur. Funding for this report was provided by voluntary contributions from AAA/CAA and their affiliated motor clubs, individual members, AAA-affiliated insurance companies, and other organizations or sources.

This publication is distributed by the AAA Foundation for Traffic Safety at no charge, as a public service. It may not be resold or used for commercial purposes without the explicit permission of the foundation. It may, however, be copied in whole or in part and distributed for free via any medium, provided the Foundation is given appropriate credit as the source of the material. The AAA Foundation for Traffic Safety assumes no liability for the use or misuse of any information, opinions, findings, conclusions, or recommendations contained in this report.

If trade or manufacturer's names are mentioned, it is only because they are considered essential to the object of this report and their mention should not be construed as an endorsement. The AAA Foundation for Traffic Safety does not endorse products or manufacturers.

## Table of Contents

---

List of Tables .....	v
List of Figures.....	vi
Executive Summary .....	1
Introduction .....	3
GDL and crash rates of novice drivers .....	3
Would GDL work for older novice drivers? .....	4
Indiana’s GDL for older novice drivers.....	5
The current study.....	6
Method .....	6
Data sources .....	6
Crash data .....	6
Driver license data .....	6
Identification of novice drivers subject to updated GDL requirements.....	7
Analyses .....	9
Results .....	9
Overall crash rates during the study period .....	9
Changes in individual crash rates.....	10
Changes in nighttime and multi-occupant crashes.....	13
Discussion.....	20
Strengths and limitations .....	22
Conclusions and future directions .....	23
References.....	24
Appendix A. Parameter estimates from the Poisson regression model of crash rates over the first 12 months of licensure.....	27
Appendix B. Parameter estimates of Poisson regression model predicting nighttime crash rate over the first 6 months of licensure.....	28
Appendix C. Parameter estimates of Poisson regression model predicting multi-occupant crash rate over the first 6 months of licensure .....	29

## List of Tables

---

Table 1. Number of drivers licensed under previous and updated Indiana licensing systems for 18- to 20-year-olds.....	8
Table 2. Crashes and per driver crash rates during initial 12 months of driving, prior to and following the update of Indiana’s GDL system for novice 18- to 20-year-old drivers.....	11
Table 3. Comparison of overall crash rates among older novice drivers licensed under updated GDL system vs. previous GDL system over the first 12 months driving, by age at licensure.....	11
Table 4. Comparison of nighttime crash rates among older novice drivers licensed under updated vs. previous GDL system over the first 6 months driving, by age at licensure. ....	15
Table 5. Comparison of multi-occupant crash rates among older novice drivers licensed under updated vs. previous GDL system over the first 6 months driving, by age at licensure.....	16
Table 6. Regression estimates predicting the percentage of nighttime crashes among older novice drivers.....	18
Table 7. Regression estimates predicting the percentage of multi-occupant crashes among older novice drivers. ....	19
Table 8. Summary measures of nighttime (10 p.m. - 5 a.m.) and multi-occupant crashes during the first 6 months driving prior to and following the update of Indiana’s GDL system for novice 18- to 20-year-old drivers.....	19

## List of Figures

---

Figure 1. Identification of cases for analysis in driver license file obtained from Indiana. ...	8
Figure 2. Monthly crash rate per 10,000 licensed drivers, by driver age, Indiana, 2013-2017.....	10
Figure 3. Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.....	12
Figure 4. Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.....	12
Figure 5. Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.....	13
Figure 6. Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.....	14
Figure 7. Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.....	14
Figure 8. Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.....	15
Figure 9. Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.....	17
Figure 10. Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.....	17
Figure 11. Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.....	18

## Executive Summary

---

On July 1, 2015, Indiana modified its Graduated Driver Licensing (GDL) system for 18- to 20-year-old novice drivers, adding nighttime and passenger restrictions to the existing mandatory 6-month learner period for all novice drivers under the age of 21. This policy change offered a unique and important opportunity to examine whether extending full GDL requirements to older novices produces safety benefits similar to those seen with younger novices.

The objective of this study was to examine several possible effects of Indiana's extension of GDL on 18- to 20-year-old novice drivers' safety. The following specific questions were addressed:

- 1) Did crash rates among 18- to 20-year-old novice drivers decline during their first year of unsupervised driving after GDL was updated?
- 2) Did nighttime crashes and multi-occupant crashes decline during the first 6 months of licensure—the time when the night and passenger limits apply—after GDL was updated?

Data were obtained from the Indiana State Police on all reportable crashes occurring between Jan. 1, 2012 and April 17, 2018. License history data for Jan. 1, 2012 to June 18, 2018 were obtained from the Indiana Bureau of Motor Vehicles. The analyses examined the 56,534 drivers who were clearly licensed completely under either the previous or updated licensing system.

An initial analysis focused on overall crash rates among 18- to 20-year-old drivers from 2012 through 2017. Age-specific monthly crash rates were computed by dividing the total number of drivers of each single year of age involved in crashes by the total number of licensed drivers of the same age during the month. In a familiar pattern for young novice drivers, the age-specific crash rates parallel one another, but are consistently lower for the older of these young drivers. There was a clear increase in crash rates among all three age groups during the study period, which likely reflects a general increase in driving—and the consequent increase in crashes—throughout the U.S. as long-term effects of the Great Recession began to abate for much of the population.

Poisson regression was used to investigate whether crash rates were lower during the first 12 months of licensure among drivers licensed under the updated system compared to those licensed under the previous system. Even after controlling for extraneous influences, 18-year-old novice drivers licensed under the updated GDL system were about 12% more likely to crash within the first 12 months of licensure than 18-year-olds licensed under the previous system (aRR = 1.12, CI: 1.05 – 1.20). A similar pattern was found for those licensed at 19 (aRR = 1.16, CI: 1.05 – 1.28). There was no reliable change in crash likelihood for 20-year-olds licensed under the updated GDL system (aRR = 0.93, CI: 0.81 – 1.06).

Two additional sets of analyses were conducted to examine whether the new GDL provisions for older novice drivers reduced nighttime and multi-occupant crashes. First, Poisson regression was used to estimate the nighttime crash rates and multi-occupant crash rates per licensed driver during the first 6 months of licensure. Crash rates between



10 p.m. and 5 a.m. were somewhat higher among novice drivers licensed at 18 and 19 under the updated system, but lower among novice drivers licensed at 20, though the differences were not statistically reliable. In contrast, multi-occupant crash rates did not change after the GDL system was updated for novice drivers licensed at 18, 19 or 20.

In another analysis, linear regression was used to investigate whether the proportion of all crashes that occurred during restricted nighttime driving hours, or with multiple occupants, declined during the first 6 months of driving after the GDL system was updated. Results indicated that the GDL update had no effect on the proportion of crashes that occurred during the restricted nighttime hours or on the proportion of crashes that involved a passenger.

To conclude, the updates to Indiana's GDL system for older novices produced no clear reduction in crashes among 18- to 20-year-old novices. This was not entirely unexpected, as the largest benefits of GDL tend to result from the lengthy learner period required of younger novice drivers prior to independent driving. The effects of night and passenger limits have not been as clearly documented among 16- and 17-year-olds. Thus, it will be especially valuable to examine the effect of GDL on older novices when a full GDL system—including a sufficiently lengthy learner period—is extended to cover 18- to 20-year-old novice drivers.

Despite the observed lack of effect for the updated Indiana licensing system for older novices, the current findings do provide valuable information for researchers and policy-makers. Merely extending elements of a system designed for young novice teen drivers to older novices—while adding exemptions to key elements presumed to be inconvenient to beginners in this age group—cannot be assumed to increase travel safety for these individuals. To be effective, a GDL system for older novices will need to be designed with greater attention to the risks to, and needs of, older novices. To understand what those are will require additional efforts from young driver researchers, as well as inquiry into whether a full GDL approach works as well for older novices as it does for younger beginners.

## Introduction

---

### GDL and crash rates of novice drivers

Motor vehicle crashes (MVCs) have long been a leading cause of death for youth in the United States. In 2017, 3,312 young people ages 15 to 20 died in MVCs and 319,620 were injured as occupants in MVCs (CDC, 2017). Nearly half of those killed were passengers, rather than drivers—most of whom were riding with a teenage driver (Insurance Institute for Highway Safety, 2016). There has been a substantial reduction in teenage driver crashes and the resulting deaths and injuries over the past 20 years as U.S. states adopted, then improved, graduated driver licensing (GDL) systems for high school age teens (Foss & Goodwin, 2003; Foss, 2007; Williams 2017).

GDL introduces teens to driving in a three-stage process, with the goal of maximizing experience for novice drivers, while simultaneously protecting them from the risks inherent in their lack of experience (Foss, 2007; Waller, 2003). Although it was long believed that high teen driver crash rates resulted mostly from risk taking, immaturity and impulsiveness, it is now well-known that the main reason for high crash rates among young teens is simply inexperience (Foss, Martell, Goodwin, & O'Brien, 2011; McCartt, Mayhew, Braitman, Ferguson, & Simpson, 2009; McKnight & McKnight, 2003).

Crash rates are highest during the initial months of unsupervised driving, regardless of driver age. Crash rates decline rapidly during the first 6 months of driving, then taper more gradually for several years (Chapman, Masten, & Browning, 2014; Curry, Pfeiffer, Durbin, & Elliott, 2015; Mayhew, Simpson, & Pak, 2003). GDL was developed specifically to take advantage of the fact that new drivers improve quickly with experience. By requiring up to a year of supervised driving in a mandatory learner period, GDL provides an opportunity for extensive experiential learning, at the same time protecting these learner drivers by requiring an experienced accompanying driver who can ensure that errors are not catastrophic.

Following completion of the learner stage, the second stage of GDL allows unsupervised driving but prohibits driving in high-risk conditions for young novices, such as nighttime driving and carrying multiple teenage passengers. This ability to drive alone during the day enables novices to learn things they cannot while accompanied by an adult (self-control, being fully in charge of the vehicle, etc.). Extensive research has documented the benefits of GDL for 16- and 17-year-old novice drivers while they are protected by these licensing provisions (Shope, 2007; Williams, 2017; Williams & Shults, 2010; Williams, Tefft, & Grabowski, 2012). Moreover, some evidence suggests that GDL reduces crash rates by 3 to 5% for up to five years after teens obtain their full license (Foss, Masten, & Martell, 2014; Masten & Foss, 2010).

There is general consensus among the research community that for 16- and 17-year-old teens, more comprehensive GDL systems produce larger crash reductions than less well-designed GDL systems (Williams, 2017). In a national study, Masten, Foss, and Marshall

(2013) identified the GDL components most effective in reducing fatal crash involvement of 16- to 17-year-olds. The findings were consistent with the principle that greater limits on high-risk exposure more effectively reduce fatal crash involvement. Specifically, compared with no learner permit requirement, requiring a learner's permit for 9 to 12 months was associated with 21% lower fatal crash incidence for 16- and 17-year-olds combined, whereas learner permit lengths of 5 to 6 months were associated with 9% lower fatal crash incidence. Learner permit lengths of fewer than 4 months produced no measurable benefit. A nighttime driving restriction for intermediate licensees starting at 10 p.m. or earlier was associated with 19% lower fatal crash rate for 16-year-olds, but not 17-year-olds.<sup>1</sup> A limit of one teen passenger for intermediate licensees was associated with a 15% lower fatal crash rate for 16- and 17-year-olds.

### **Would GDL work for older novice drivers?**

In nearly all U.S. states, GDL applies only to new drivers under the age of 18. Once teens turn 18, they can obtain a regular adult license with little or no supervised driving experience, nor any restrictions on driving in high-risk conditions. However, results from the few studies that specifically address the crash rates of older novices indicate that older novices, and especially those age 18 to 20, also experience a high initial crash rate, followed by a rapid decline over the first year of driving (Curry, Foss, & Williams, 2017; Curry, Metzger, Williams, & Tefft, 2017). Chapman et al. (2014) found that 18-year-old novices had higher crash rates than younger novices. These recent findings, along with evidence that a substantial proportion of teens wait until age 18 or older to begin driving (Shults & Williams, 2017; Tefft, Williams, & Grabowski, 2014), have prompted some practitioners and policy makers to suggest extending GDL to 18- to 20-year-old novices (GHSA, 2018).

Outside the U.S. (primarily Canada and Australia), GDL is viewed largely as a traffic law and applies to most novice drivers regardless of age. In the U.S., on the other hand, GDL is primarily a policy to address a significant adolescent health risk that has focused largely on high-school age teens. Currently, only seven jurisdictions in the U.S. apply some form of GDL to novice drivers over the age of 17: Connecticut, Indiana, Maine, Maryland, Minnesota, New Jersey and the District of Columbia (Williams, 2017).

There is clearly a need to reduce crashes among novice drivers ages 18 and older, but research is scarce to indicate what kind of GDL provisions would be most effective, or indeed whether GDL is even feasible for beginners of this age (Curry et al., 2017a). Curry et al. (2017b) found that early night driving (9 to 11 p.m.) and carrying multiple passengers remain high-risk scenarios for novice drivers up to age 21, suggesting the potential value of

---

<sup>1</sup> The lack of an effect for 17-year-olds is likely because this particular element of GDL lasts only 6 months in most states, so the majority of 17-year-olds do little—if any—of their driving with a night limit still in effect. In contrast, virtually all 16-year-old novices are subject to a night limit for much of their first year as a licensed driver.

prohibiting older novices from driving in these conditions during their initial months of (unsupervised) driving.

GDL reduces crashes for 15- to 17-year-old drivers largely by reducing exposure to high-risk circumstances in the initial 12 to 18 months of driving. Accordingly, the question of whether GDL would benefit older novices depends largely on whether it would similarly reduce their exposure to that of younger novices. Drivers aged 18- to 20-years-old, whether novice or experienced, have different exposure and travel patterns than younger drivers. Compared with their younger counterparts, 18- to 20-year-olds drive substantially more, as they are more likely to be living away from parents, employed full time, married and may even have children of their own (Lee, Wickrama, O'Neal, & Prado, 2018). Thus, it is unclear whether a GDL system that was originally designed for high school-age teens would be workable for older novices, or achieve similar crash reductions (Foss, 2007; Curry et al., 2017a).

The effect of extending GDL requirements to older novice drivers, together with the mechanism of such effects, or lack thereof, remains an important research question to be addressed.

### **Indiana's GDL for older novice drivers**

On July 1, 2015, Indiana modified its licensing system for 18- to 20-year-old novice drivers. This update added two other GDL components to the existing mandatory 6-month learner period, putting in place a full GDL system with the three key beneficial elements (Masten et al., 2013) for all novice drivers under the age of 21. It should be noted that the other key element of GDL, a mandatory learner period, was already in place for 18- to 20-year-old novices. Indiana introduced a 6-month learner permit requiring 50 hours of supervised practice for all beginners on July 1, 2010.<sup>2</sup>

The 2015 change added two protective limits during the first 6 months of driving with an operator's license for beginning 18- to 20-year-old drivers. These previously applied only to novices under age 18. Starting July 1, 2015, older novices under 21 were required to have a supervising driver<sup>3</sup> on trips between 10 p.m. and 5 a.m. and/or when carrying non-family members as passengers. There are exemptions to the nighttime driving limit for trips to and from work, school-sanctioned activities and religious events.

This policy change offers a unique and important opportunity to examine whether extending GDL requirements to older novices produces safety benefits similar to those seen with younger novices. Curry et al. (2017a) emphasized that evaluations of such policy

---

<sup>2</sup> In an exemption from GDL requirements that is more likely to be found in systems applying to older novices, learner permit holders in Indiana can request a "hardship waiver" to reduce the time they are required to hold a permit before getting a license. In summary, both before and after July 2015, the typical beginning 18- to 20-year-old driver was required to hold a permit for 180 days before getting a license, but it was possible for drivers to get a license in less than 180 days.

<sup>3</sup> Supervisor must be a licensed driver  $\geq$  age 25, or a spouse  $\geq$  age 21 who has a valid driver license.

changes are critically needed to inform future consideration of whether GDL is workable and beneficial for older novice teenage drivers.

## **The current study**

The objective of this study was to examine the effects of Indiana’s extension of GDL on 18- to 20-year-old novice drivers’ safety. The following specific questions were addressed:

- 1) Did crash rates among 18- to 20-year-old novice drivers during their first year of unsupervised driving decline after GDL was updated?
- 2) Was there a reduction in nighttime crashes and multi-occupant crashes during the first 6 months of licensure after GDL was updated?

## **Method**

---

### **Data sources**

#### *Crash data*

Data were obtained from the Indiana State Police on all police-reported<sup>4</sup> crashes occurring between Jan. 1, 2012 and April 17, 2018. This provided three and a half years of data for the baseline period, and nearly three years of data for the updated GDL period. In addition to variables describing crash and vehicle characteristics, descriptive information about drivers, injured occupants and the total number of occupants were provided for each crash.

An intermediate license period, with nighttime and passenger restrictions, is the essential feature of the updated GDL system for older novices. The time of crash is readily available in the data, but Indiana does not capture detailed information—including ages—about non-injured passengers involved in crashes. Accordingly, only the total number of passengers in each crash-involved vehicle could be determined consistently. Indiana does not issue a separate intermediate license. Instead, the first 6 months after obtaining a regular license allowing unsupervised driving constitutes the “intermediate license” period.

#### *Driver license data*

License history data for Jan. 1, 2012 to June 18, 2018 were obtained from the Indiana Bureau of Motor Vehicles (BMV). These included driver license number, date of birth, license class (e.g., learner permit, operator license, motorcycle, commercial), and the issue date of each license class. This was a time-based file rather than person-based file; consequently, the first license available in the data set was not necessarily the first license

---

<sup>4</sup> In Indiana, a crash is reportable if it involves an injury or the total amount of damage to involved vehicles is \$1,000 or more.

an individual had obtained. For example, consider a case in which the first licensing record for an individual in the data set was an operator license issued on Jan. 2, 2012 when the person was 20 years old. From these data it cannot be determined whether (a) this person had a previous operator license and this was a renewal, (b) this was a first operator license following a learner permit or (c) this was a the person's first Indiana-issued license but not his or her first operator's license (e.g., a license issued to a person who had moved to Indiana and was already licensed elsewhere). To address this limitation, only those drivers whose learner permit information was available in the data were included in the study.

In addition to individual license data, Indiana BMV provided a summary table of quarterly count of licensees, by single year of age, from 2013 to 2017. This information was used to compute crash rates per licensed driver in further analyses.

### **Identification of novice drivers subject to updated GDL requirements**

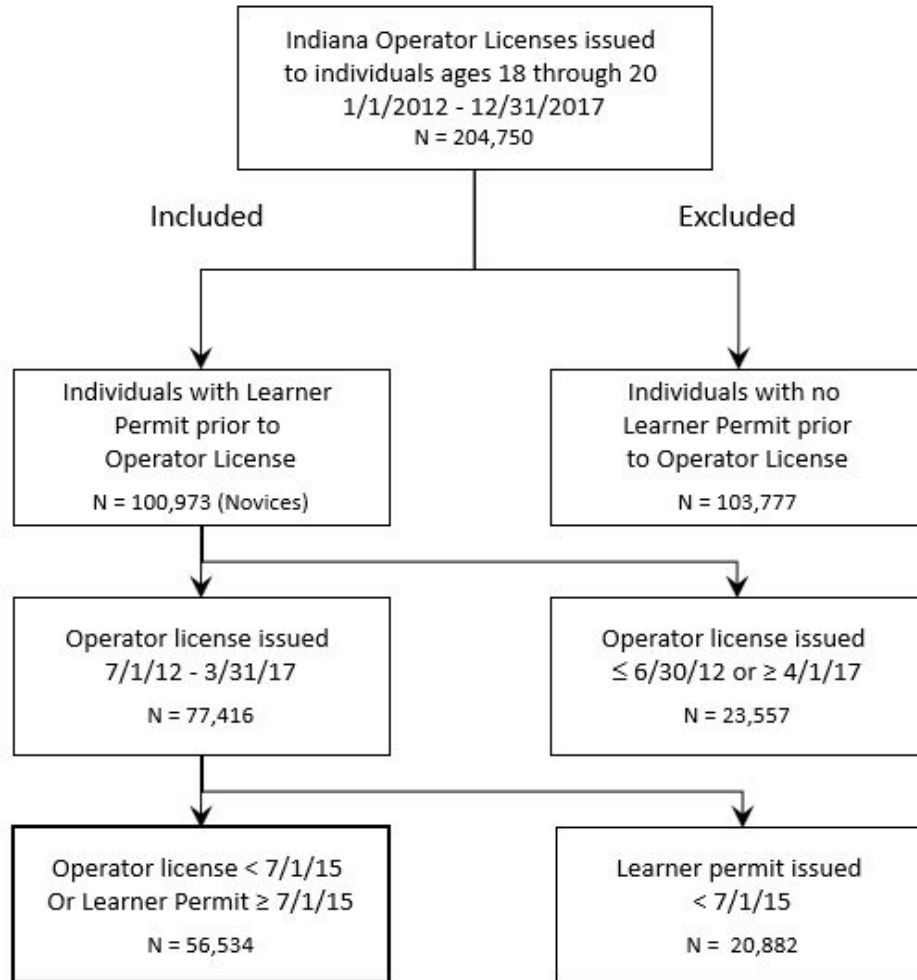
The primary goal of the study was to compare crashes among older novice drivers before and after GDL licensing requirements were updated for 18- to 20-year-old novice drivers in Indiana. For the analyses, there were 204,750 individuals identified as older novice drivers; that is, individuals who obtained a learner permit, followed by an operator license issued at age 18, 19, or 20.

Drivers licensed after March 1, 2017 were excluded from the analysis, to ensure that all crashes in drivers' first full year of licensed driving would be included in the study.

Next, the researchers attempted to determine which novice 18- to 20-year-old drivers were licensed under the system in effect prior to July 1, 2015 who were also licensed under the updated system. Unfortunately, despite extensive efforts, the researchers were unable to obtain definitive information about whether individuals who had obtained a learner permit prior to July 1, 2015 were exempt from the new GDL requirements (night and passenger limits for 6 months) for persons issued an operator license after that date.

"Grandfathering," to avoid changing licensing requirements for individuals who began the licensing process under a system that is subsequently altered, is common when driver licensing requirements are changed. Thus, drivers issued a learner's permit before July 1, 2015 but licensed after this date were excluded from this study.

Table 1 shows the number of individuals, by age, who were licensed under the previous and updated licensing systems. The analyses reported here examined the 56,534 drivers (44,732+11,802) who were licensed completely under either the previous or updated system. This excluded those who obtained a learner permit prior to the GDL update but obtained a license after the GDL update. Figure 1 summarizes the process through which the final sample was selected.



**Figure 1.** Identification of cases for analysis in driver license file obtained from Indiana.

**Table 1.** Number of drivers licensed under previous and updated Indiana licensing systems for 18- to 20-year-olds.

Licensing system experienced	Age at initial licensing			Total
	18	19	20	
Permit and license prior to GDL update	23,992	12,944	7,796	44,732
Permit and license after GDL update	6,823	3,221	1,758	11,802
Permit prior to GDL update; license after GDL update*	10,649	6,149	4,084	20,882
<b>Total</b>	<b>41,464</b>	<b>22,314</b>	<b>13,638</b>	<b>77,416</b>

\* These drivers were excluded in the following analyses because it was unclear whether the new requirements during the first 6 months of licensing applied to them.

## Analyses

As a preliminary analysis, monthly crash rates per licensed driver for each age group were examined from 2013 through 2017 to look for any obvious change following the updated licensing policy on July 1, 2015. To address Research Question 1, Poisson regression was used to determine whether the crash rates of novice 18- to 20-year-old drivers during their first year of unsupervised driving changed after the licensing system was updated.

The regression models were estimated using generalized estimating equations (GEE), with a first-order autoregressive correlation matrix and empirical variance to account for correlation due to repeated (monthly) measurements (Hardin & Hilbe, 2013; Liang & Zeger, 1986). In addition, crash rates of drivers aged 25-34 and gasoline prices were included in the model as covariates to account for other factors that can affect driving and crashes (e.g., weather, roadway conditions, and economic conditions). Further, an interaction term between age and each of the predictors was included to examine whether novice drivers of different ages were affected differently by the policy change and other contextual factors represented by gasoline price and the crash rate of 25- to 34-year-old drivers.

To address Research Question 2, Poisson regression was used to investigate whether rates of nighttime and multi-occupant crashes changed during the first 6 months of licensure for 18- to 20-year-old novice drivers following the policy change. In addition, a series of linear regression models were estimated to examine whether the proportion of crashes that occurred during restricted night driving hours or involving multiple occupants differed among those licensed under the updated system versus the previous system.

## Results

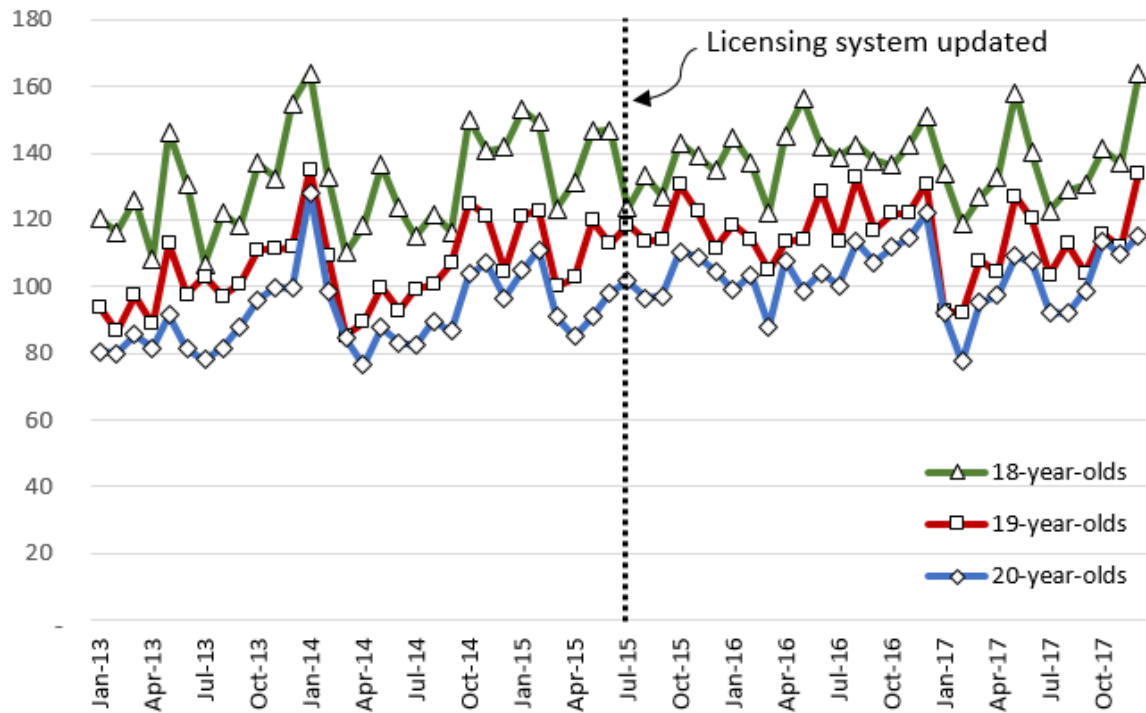
---

### Overall crash rates during the study period

After several years of decline—likely due to reductions in driving during the Great Recession—crashes began increasing in the U.S. in 2014. Because the Indiana licensing system was updated at about this time, it is important to consider trends in crash rates among 18- to 20-year-old Indiana drivers, to determine whether a general trend might confound analyses of effects of the new licensing requirements. Age-specific monthly crash rates were computed by dividing the total monthly crash count for each age group (18, 19 or 20) by the total number of licensed drivers of that age during the month. (The license counts were only available per quarter, thus the same license counts were used for all three months in each quarter.)

These crash rates provide a crude look at the crash likelihood among all 18- to 20-year-old drivers, most of whom were licensed at younger ages and thus would not have been affected by the changes to the licensing system, during the study period. Figure 2 shows the monthly age-specific crash rates per 10,000 drivers from Jan. 2013 to Dec. 2017.





**Figure 2.** Monthly crash rate per 10,000 licensed drivers, by driver age, Indiana, 2013-2017.

In a familiar pattern for young novice drivers, the age-specific crash rates parallel one another, but are consistently lower for older novices. There was a small, but clear increase in crash rates among all three age groups during the study period. This probably reflects the general increase in driving—and the consequent increase in crashes—that occurred throughout the U.S. as the long-lasting effects of the Great Recession finally began to abate for much of the population.

### Changes in individual crash rates

To look closely at whether the new licensing requirements reduced crash rates, the crash experience of newly-licensed individuals during their initial 12 months of unsupervised driving was examined. Figures 3-5 show the decline in crashes, for each age group, typically found among newly licensed drivers as they gained experience during their initial year of driving (Foss et al., 2011; Lewis-Evans, 2010). However, as shown in Table 2, the crash rate per 10,000 licensed drivers increased after the licensing system was updated.

**Table 2.** Crashes and per driver crash rates during initial 12 months of driving, prior to and following the update of Indiana’s GDL system for novice 18- to 20-year-old drivers.

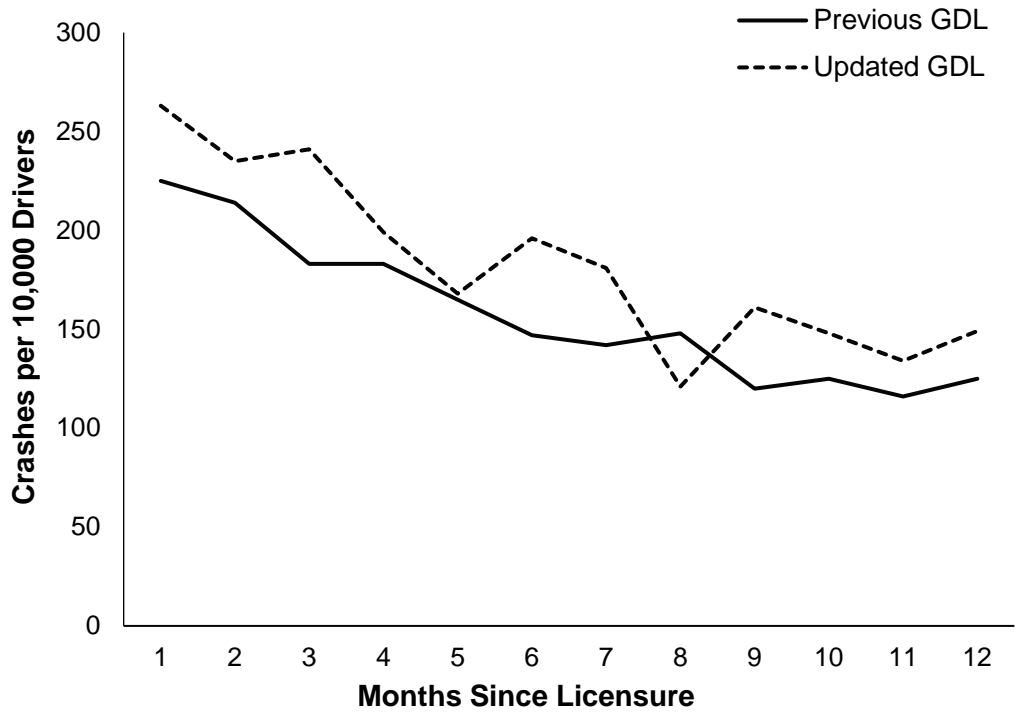
	Prior to GDL update	Following GDL update
<b>Licensed at age 18</b>		
Drivers	23,992	6,823
Crashes	4,558	1,503
Crash rate*	1,899	2,202
<b>Licensed at age 19</b>		
Drivers	12,944	3,221
Crashes	2,234	671
Crash rate*	1,725	2,083
<b>Licensed at age 20</b>		
Drivers	7,796	1,758
Crashes	1,306	346
Crash rate*	1,675	1,797
<b>Total (licensed at 18-20)</b>		
Drivers	44,732	11,802
Crashes	8,098	2,490
Crash rate*	1,810	2,109

\* per 10,000 licensed drivers

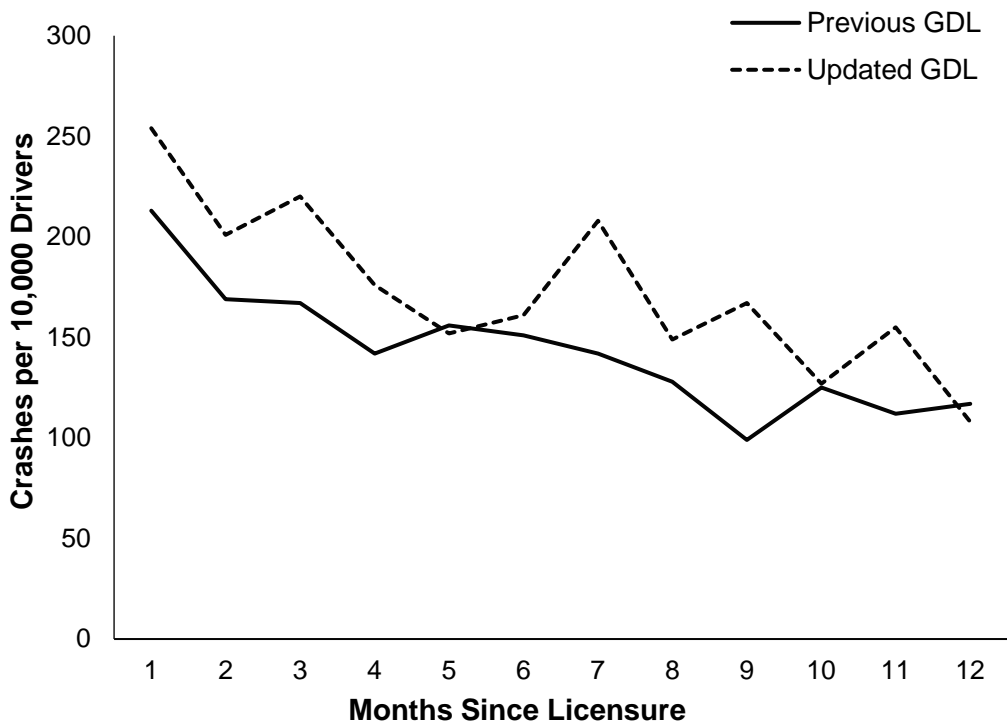
Detailed results of the Poisson regression analysis are shown in Appendix A. As summarized in Table 3, the crash rates during the first 12 months of licensure were generally higher following the update to the licensing system. Even after attempting to control for the extraneous influences mentioned above, 18-year-old novice drivers licensed under the updated GDL system were 12% more likely to crash within the first 12 months of licensure than 18-year-olds licensed under the previous system (adjusted Rate Ratio [aRR] = 1.12, CI: 1.05 – 1.20). A similar pattern was found for those licensed at 19 (aRR = 1.16, CI: 1.05 – 1.28), but there was no reliable difference in crash likelihood for 20-year-olds licensed under the updated GDL system (aRR = .93, CI: 0.81 – 1.06). These patterns are clearly visible in monthly crash rate trajectories of the previous and more recent licensing cohorts shown in Figures 3-5.

**Table 3.** Comparison of overall crash rates among older novice drivers licensed under updated GDL system vs. previous GDL system over the first 12 months driving, by age at licensure.

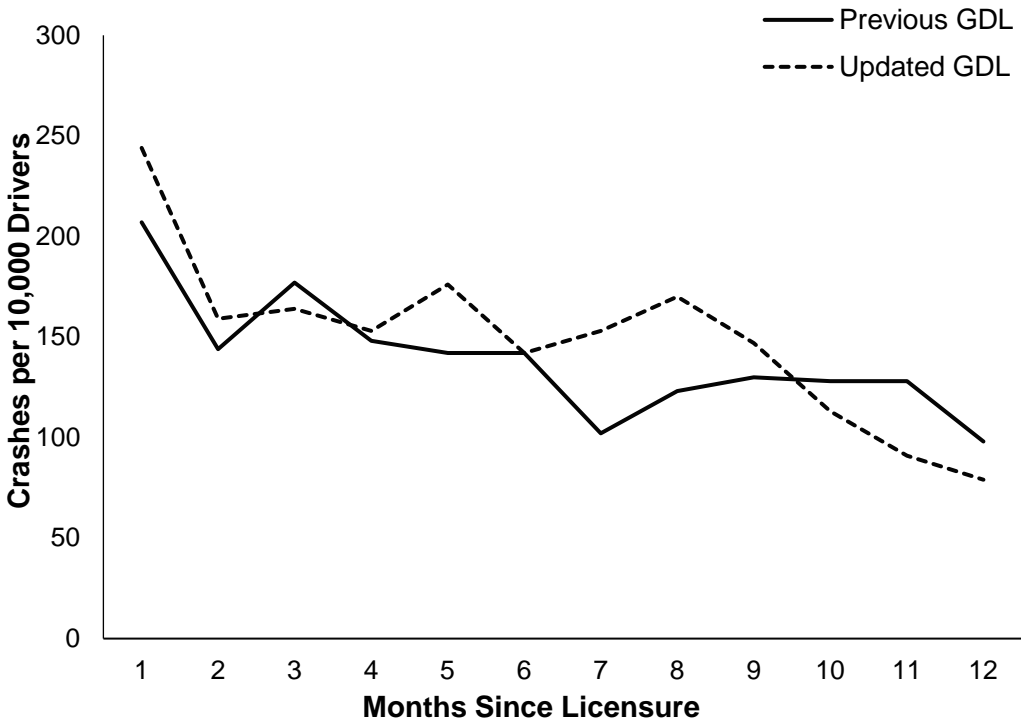
Licensing Age	Adjusted Rate Ratio (95% Confidence Interval)
18	1.12 (1.05 – 1.20)
19	1.16 (1.05 – 1.28)
20	0.93 (0.81 – 1.06)



**Figure 3.** Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.



**Figure 4.** Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.

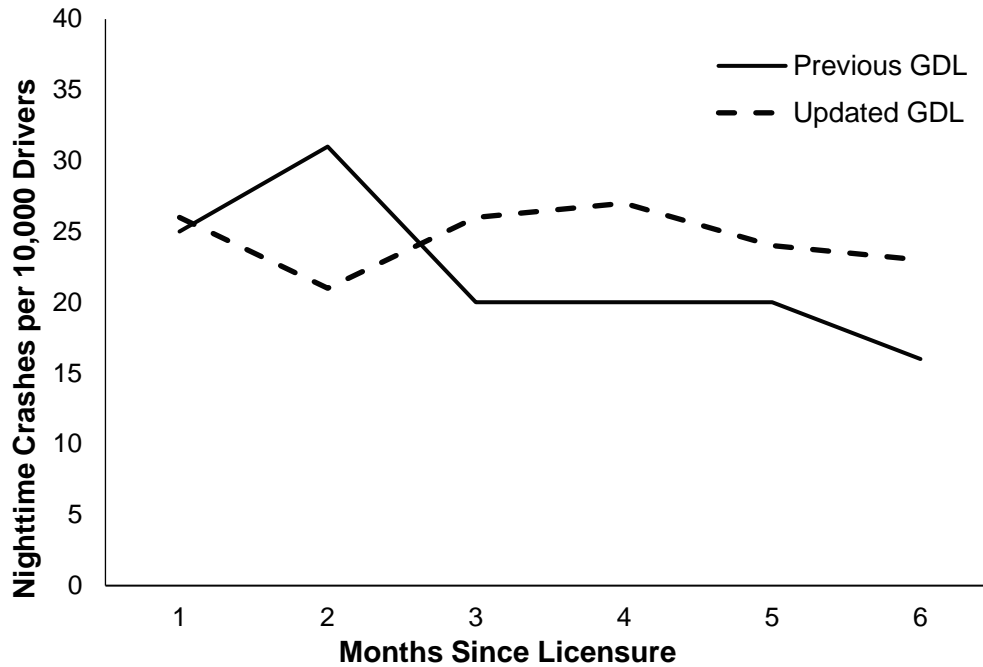


**Figure 5.** Monthly crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.

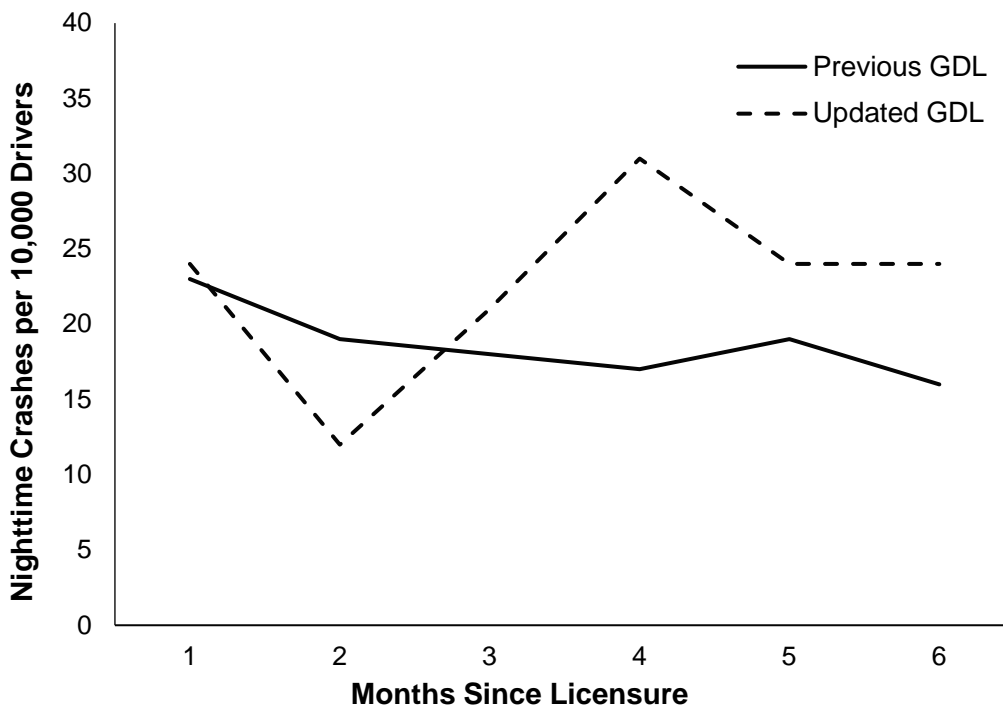
### Changes in nighttime and multi-occupant crashes

The primary mechanism by which the updated Indiana licensing system would be expected to reduce crashes among novice 18- to 20-year-old drivers is through a 6-month reduction in exposure to nighttime (10 p.m. – 5 a.m.) crashes, and to the elevated risk of crashing when carrying passengers. In the 6 years of data available for analysis, about 12% of crashes during the first 6 months driving occurred between 10 p.m. and 5 a.m. and about 30% involved at least one passenger.

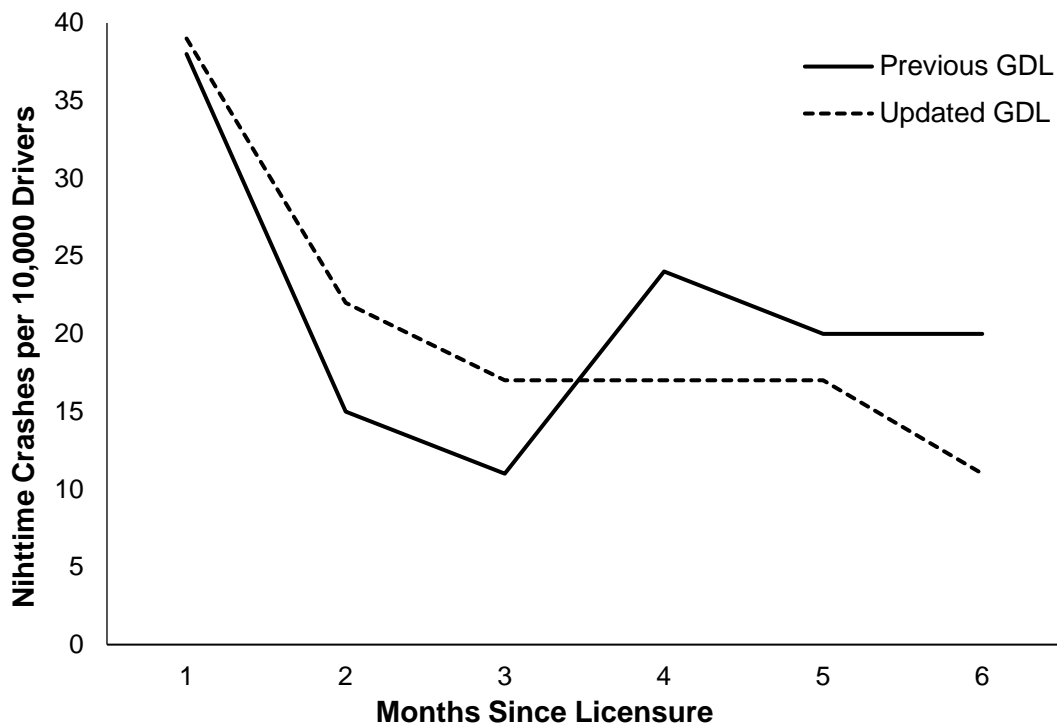
To examine whether the new GDL provisions for older novices reduced nighttime and multi-occupant crashes, two sets of analyses were conducted. First, Poisson regression was used to estimate nighttime crash rates (Figures 6 to 8) and multi-occupant crash rates (Figures 9 to 11) per licensed driver. It is worth noting that these rates are based on a rather small number of incidences, which explains the high variability from month-to-month.



**Figure 6.** Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.



**Figure 7.** Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.



**Figure 8.** Nighttime (10 p.m. – 5 a.m.) crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.

The change in nighttime crash rates among new drivers licensed under the updated GDL system differed by age (detailed results are shown in Appendix B). As summarized in Table 4, crash rates from 10 p.m. – 5 a.m. were somewhat higher among novice drivers licensed at ages 18 and 19 under the updated system than those licensed under the previous system, but lower among novice drivers licensed at age 20. This is similar to the findings for overall crash rates; however, the differences for nighttime crash rates were not statistically reliable.

**Table 4.** Comparison of nighttime crash rates among older novice drivers licensed under updated vs. previous GDL system over the first 6 months driving, by age at licensure.

Licensing Age	Adjusted Rate Ratio (95% Confidence Interval)
18	1.32 (0.97 – 1.78)
19	1.30 (0.84 – 1.99)
20	0.78 (0.45 – 1.36)

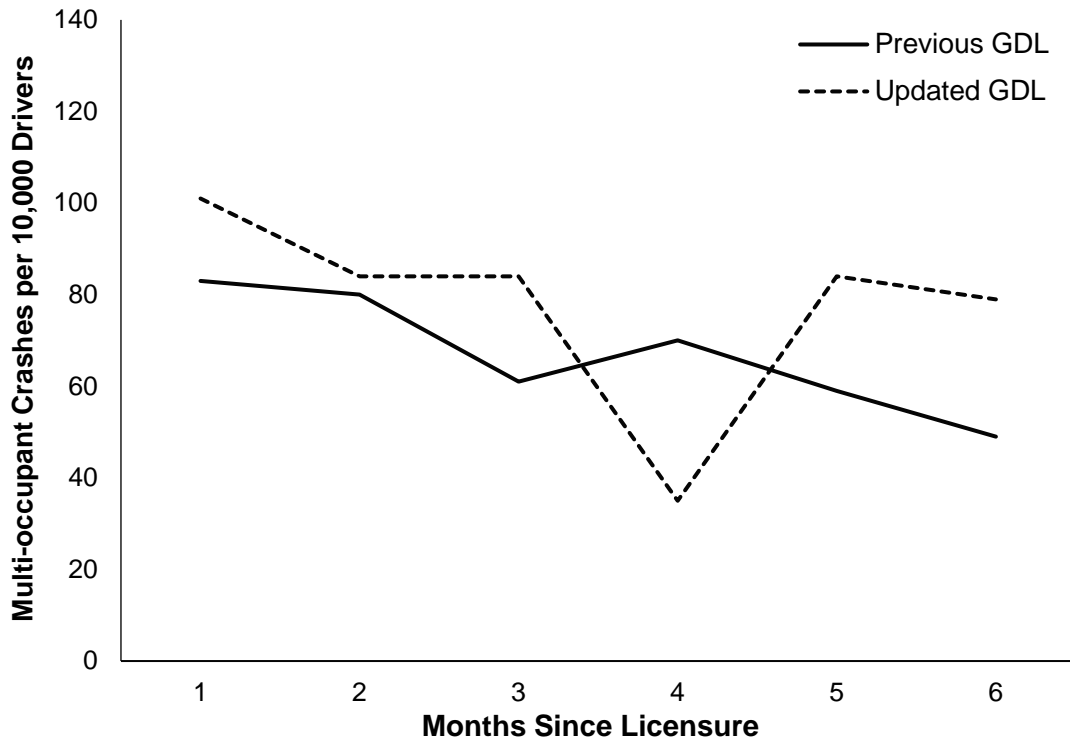
As noted previously, Indiana police crash report data include no information about uninjured passengers involved in crashes, but the total number of occupants in each involved vehicle is recorded. This can be used to identify whether a crash-involved driver had any passengers. However, this is a crude indicator of compliance with the new GDL requirements for older novices because of exemptions to the passenger carrying restriction. For example, the data do not make it possible to distinguish between prohibited (young) and acceptable (qualifying licensed adult) passengers. Further limiting ability to determine whether the new GDL requirements reduced passenger-involved crashes is the fact that the occupant count data were missing for all crash reports from calendar year 2017. Consequently, only crashes in the first 18 months following the update to the GDL system could be included in the analysis of passenger involvement.

As shown in Table 5, results of Poisson regression indicate that multi-occupant crash rates did not change after the GDL system was updated for novice drivers licensed at 18, 19 or 20. (Detailed output are shown in Appendix C.) The 95% confidence intervals for the adjusted rate ratios contained 1 for each age group.

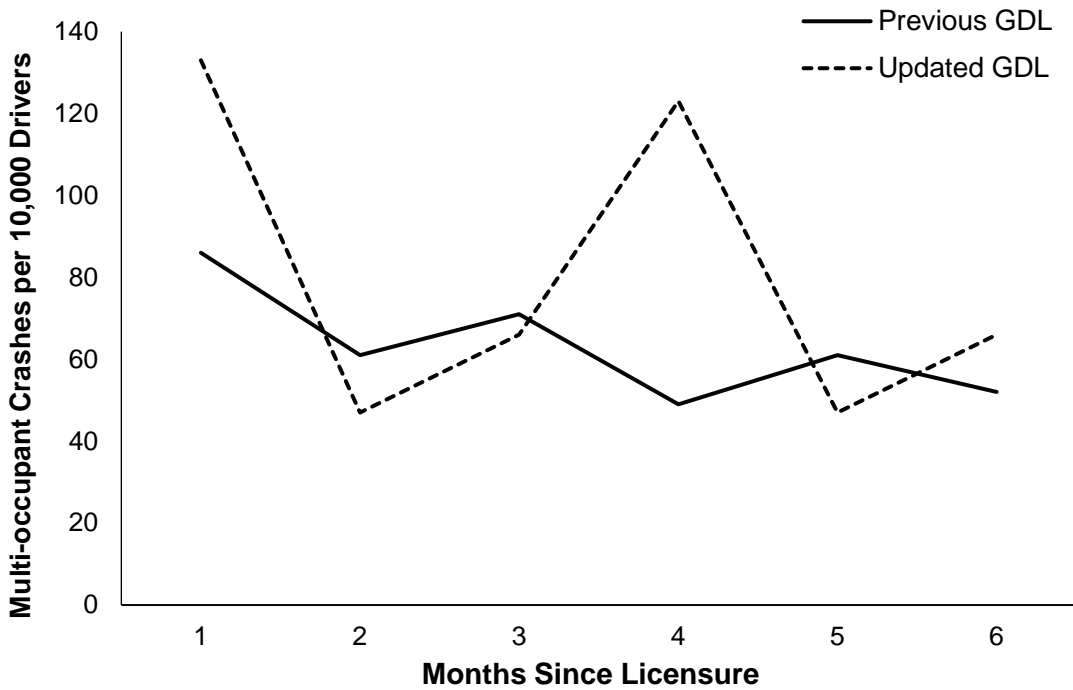
**Table 5.** Comparison of multi-occupant crash rates among older novice drivers licensed under updated vs. previous GDL system over the first 6 months driving, by age at licensure.

Licensing Age	Adjusted Rate Ratio (95% Confidence Interval)
18	1.08 (0.88 – 1.32)
19	1.13 (0.83 – 1.52)
20	0.92 (0.61 – 1.39)

Nighttime and multi-occupant crash rates do not necessarily capture the effect of the new provisions in the updated Indiana licensing system. This is because the rates can be affected by the overall amount of driving, as well as compliance with the limits on night driving and carrying passengers. If the overall amount of driving increased after July 2015 and these new licensing provisions were not 100% effective in preventing night or multi-occupant crashes, the crash rates for those types of crashes could have increased even though compliance was high and the provisions were functioning as intended. Similarly, if driving declined after July 2015, even if there was no compliance at all with the night and passenger provisions, the per driver crash rates for those types of crashes would have decreased. In addition, if drivers were more competent in avoiding crashes following July 2015, for whatever reason, their crash nighttime and multi-occupant per driver crash rates would decline irrespective of their compliance with these new GDL provisions. Therefore, the apparent effect of the new provisions was also investigated by examining the proportion of all crashes in the affected age groups that occurred during the restricted nighttime hours, or those involving passengers, before and after the updated licensing system took effect.

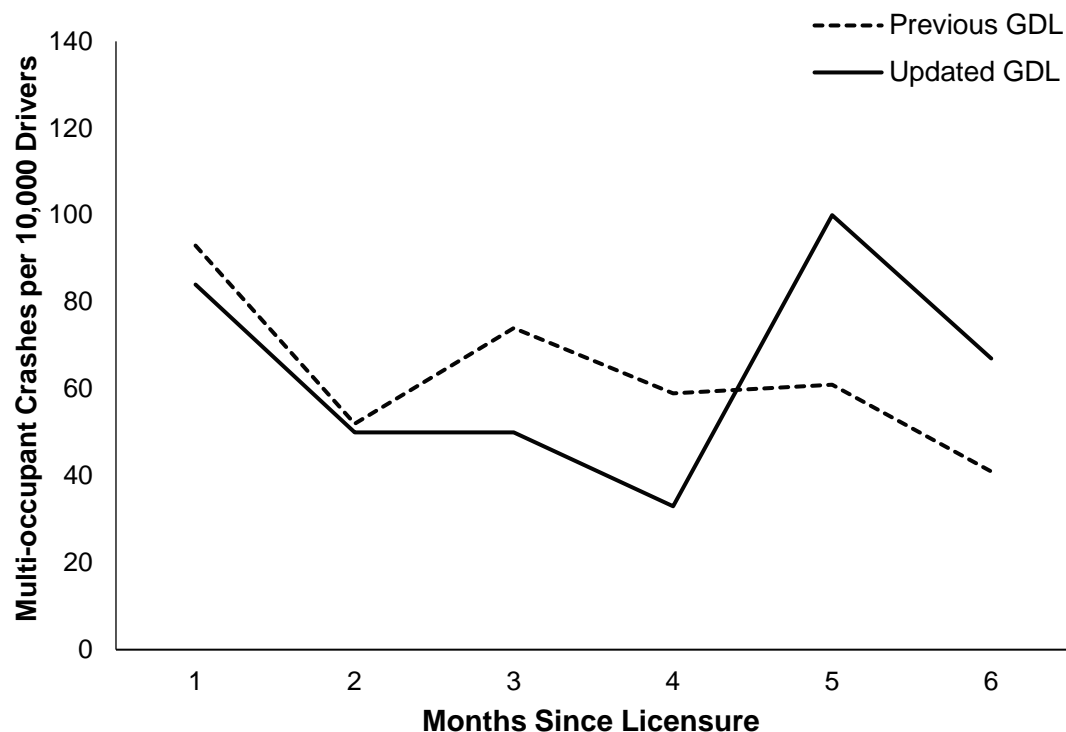


**Figure 9.** Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 18.



**Figure 10.** Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 19.





**Figure 11.** Multi-occupant crash rates per 10,000 licensed drivers, novice drivers licensed at age 20.

Linear regression models were used to determine whether the proportion of all crashes that occurred from 10 p.m.-5 a.m., or with multiple occupants, declined during the first 6 months of driving after the GDL system was updated. As shown in Table 6, the GDL update had no effect on the proportion of all crashes that occurred during the restricted nighttime hours, suggesting either that older novices were not complying with the limit on unsupervised night driving, or the presence of a required licensed adult supervisor did not create the protective effect it provides among 16-17-year-old novices. Somewhat surprisingly, the percentage of nighttime crashes was lower among novice drivers licensed at age 20 ( $\beta = -.56$ ,  $p = .01$ ), compared with 18- and 19-year-old novice drivers. However, this is a small difference and was statistically significant only because the number of cases was large.

**Table 6.** Regression estimates predicting the percentage of nighttime crashes among older novice drivers.

Parameter	Estimate	Standardized Estimate	Standard Error	p
Intercept	0.12	0.00	0.01	<.001
Licensing system (updated)	0.00	0.00	0.01	1.00
License age (19)	-0.003	-0.05	0.01	0.83
License age (20)	-0.04	-0.56	0.01	0.01
Licensing system x license age (19)	0.01	0.11	0.02	0.64
Licensing system x license age (20)	-0.02	-0.21	0.02	0.35

Table 7 shows that there was also no effect of the new licensing requirements on the proportion of crashes that involved a passenger. However, as noted above, the measure of multi-occupant crashes is at best a crude indicator of novice drivers' compliance with the updated GDL system's passenger restriction.

**Table 7.** Regression estimates predicting the percentage of multi-occupant crashes among older novice drivers.

Parameter	Estimate	Standardized Estimate	Standard Error	p
Intercept	0.36	0.00	0.02	<.001
Licensing system (updated)	-0.03	-0.23	0.04	0.44
License age (19)	0.02	0.15	0.04	0.59
License age (20)	0.03	0.22	0.04	0.41
Licensing system x license age (19)	0.06	0.31	0.06	0.31
Licensing system x license age (20)	0.04	0.22	0.06	0.49

**Table 8.** Summary measures of nighttime (10 p.m. - 5 a.m.) and multi-occupant crashes during the first 6 months driving prior to and following the update of Indiana's GDL system for novice 18- to 20-year-old drivers.

	Prior to GDL update	Following GDL update
<b>Licensed at age 18</b>		
10 p.m. – 5 a.m. crash rate*	134	150
Multi-occupant crash rate*	404	469
10 p.m. – 5 a.m. crash proportion	0.12	0.12
Multi-occupant crash proportion	0.36	0.33
<b>Licensed at age 19</b>		
10 p.m. – 5 a.m. crash rate*	115	139
Multi-occupant crash rate*	381	484
10 p.m. – 5 a.m. crash proportion	0.12	0.12
Multi-occupant crash proportion	0.38	0.41
<b>Licensed at age 20</b>		
10 p.m. – 5 a.m. crash rate*	130	125
Multi-occupant crash rate*	382	386
10 p.m. – 5 a.m. crash proportion	0.14	0.12
Multi-occupant crash proportion	0.40	0.41
<b>Total (18-20)</b>		
10 p.m. – 5 a.m. crash rate*	128	144
Multi-occupant crash rate*	394	461
10 p.m. – 5 a.m. crash proportion	0.12	0.12
Multi-occupant crash proportion	0.37	0.36

\* per 10,000 licensed drivers

Table 8 provides a summary of the nighttime and multi-occupant crash rates and proportions before and after the licensing system was updated. It is noteworthy that rates of crashes involving conditions that new drivers were supposed to be avoiding under the updated GDL system seemed to have increased after July 2015, when the updated system took effect. This appears, however, to merely reflect increased driving, since there were essentially no changes in the proportion of crashes that occurred in these conditions. This is also consistent with the overall increase in crash rates noted above.

## Discussion

---

There is an urgent need for research to inform policy decisions about whether to extend traditional GDL requirements to older novice drivers. To address this need, this study examined whether Indiana's updated GDL system influenced crashes and crash rates of 18- to 20-year-old novice drivers. Starting July 1, 2015, novices under 21 in Indiana were required to have a supervising driver during two conditions:

- on trips between 10 p.m. and 5 a.m.
- when carrying non-family members as passengers.

A mandatory learner period of 6 months was already in place for 18- to 20-year-old novices. Results showed the crash rates of 18- to 20-year-old drivers did not decrease as a result of the update to Indiana's GDL system. In fact, crash rates during the first year of unsupervised driver were higher for 18-year-olds and 19-year-olds licensed under the updated system than those licensed under the old system and there was no difference among those licensed at 20 under the two systems. Moreover, there was no apparent effect on either nighttime or multi-occupant crashes, although the only measure of whether occupants were involved in crashes was not ideal for assessing the presence of prohibited passengers.

Extensive research over the past 2 decades shows that GDL reduces crashes of 16- and 17-year-old drivers (Shope, 2007; Williams, 2017; Williams & Shults, 2010; Williams et al., 2012). It does so largely by protecting inexperienced drivers from high-risk driving conditions (Foss, 2007; Waller, 2003).

GDL lessens the risk resulting from young novice drivers' initial lack of experience by requiring them to be accompanied by an experienced adult driver for their first 6-12 months of driving (i.e., the learner permit period). During the intermediate license period, the risk-reduction principle continues via restrictions on specific conditions known to be particularly hazardous for novice drivers. This enables beginners to learn from experience while being largely protected from the high risk their lack of experience entails.

Most crash-inducing errors are precluded, or their effects minimized, by the experienced supervising driver. In addition, requiring an accompanying adult means beginners drive less during their learner permit period than is the case when there is no mandated period of adult supervision. This further reduces the likelihood of a crash by limiting exposure of inexperienced drivers. The intermediate license period functions similarly by reducing

exposure of inexperienced drivers to the most dangerous conditions (at night, with young passengers).

The 2015 update of the Indiana licensing system for beginning 18- to 20-year-old drivers converted it to a full GDL system. It was already the case that, with a few limited exceptions, these older novices had to spend their initial 6 months driving only when accompanied by an experienced driver. In other words, the mandatory learner period of GDL was already in place. The update added an intermediate license period, extending for 6 months the requirement of a supervising driver when driving at night (10 p.m. – 5 a.m.) or with young passengers. Therefore, the effect of the revised system should reflect 6 months of additional driving by 18- to 20-year-old novices now protected from crashing at night or with prohibited (young) passengers.

Even though driving at night is more risky than other times, crashes occurring from 10 p.m. – 5 a.m. constitute a small proportion of all crashes among young drivers (because relatively little driving occurs this late). In Indiana, they represent about 12% of all crashes among 18- to 20-year-old newly licensed drivers. Hence, completely eliminating those would have only a small effect on the total number of crashes and the crash rate per licensed driver. The lack of any apparent decline either in total crashes, or in the percentage of crashes that occurred during restricted hours suggests essentially no benefit of adding this element to the licensing system for new drivers first licensed at ages 18-20. It is unclear why that is the case. Previous research indicates that young novice drivers are highly likely to comply with night and passenger limits, and research in New Jersey indicates that older novices do so as well (Curry, Pfeiffer & Elliott, 2017), so it seems unlikely that 18- to 20-year-old novice drivers in Indiana simply ignored this requirement.

There are other possible explanations for the failure of the new 6-month night driving protection to affect crashes of 18- to 20-year-old novices. First, numerous exemptions to this requirement were permitted. Trips to and from work, school-sanctioned activities, and religious events were allowed without an accompanying licensed driver. The percent of nighttime trips for these purposes is unknown, but these exemptions likely reduced the potential benefit of the requirement with respect to crash reduction. In particular, driving to and from school and/or work may be necessary for many older novices, more so than for their younger counterparts. Second, a spouse as young as 21 with a driver license qualifies as a supervising driver, even though he/she may be a relatively inexperienced driver and may not effectively moderate the young driver's behavior and performance to the same degree as a parent would. Hence, the elements of the accompanying driver requirement that work well for younger teen novices may simply not work in the same way for at least some older novices.

In seeking to shed light on this matter, and whether or how a night limit might be beneficial to older novices, research will need to address complexly intertwined issues that contribute to crash rates in this age group, varying travel needs of older novices, as well as political feasibility of imposing protective limits on persons who have reached the broadly recognized formal “age of adulthood” (age 18) in the United States. An indication of the political complexity of this issue is the fact that GDL systems outside the U.S. that apply to novices 18 or older rarely include the kind of night driving protection during an

intermediate license period that is the hallmark of U.S. GDL systems for young novices (Senserrick & Williams, 2015).

Crashes involving a non-family passenger are substantially more common among young novice drivers than nighttime crashes. However, the increased risk of *non-fatal* crashes for young novice drivers associated with carrying passengers is not well-established and this is especially the case for 18- to 20-year-old novices. Passengers appear to have a greater effect on fatal crashes (Ouimet, Pradhan, Brooks-Russell, Ehsani, Berbiche, & Simons-Morton, 2015; Tefft, Williams & Grabowski, 2013), but the overall crash-reducing effect of limiting non-family passengers is likely to be quite small. The potential effect of the Indiana passenger limit is particularly difficult to assess. It applies to non-family passengers rather than young passengers, but research shows older passengers (> age 35) are generally protective against fatal crashes (Tefft et al., 2013).

Unfortunately, due to lack of adequate data, it was not possible to precisely measure the presence of restricted versus non-restricted passengers in crashes, thus the finding that the neither the rate of older novice drivers' crashes with passengers nor the proportion of their crashes in which passengers were present decreased under the updated GDL system should be considered only a crude indicator of the possible effect of this change.

Overall crashes and nighttime crashes for 18- and 19-year-old novice drivers increased following the update to Indiana's GDL system. There is no plausible reason that crashes would have increased as the result of the new Indiana licensing requirements. Rather, this increase is probably explained by an increase in the amount of driving—and thus increased exposure to crashing—as the economy continued to improve nationwide and in Indiana. The analysis attempted to adjust for this by including gasoline prices, employment rates, and crash rates of slightly older young adult drivers, but none of these is an ideal indicator of the amount of driving done by 18- to 20-year-olds generally nor the specific subset of them licensed at age 18 or older in particular.

### **Strengths and limitations**

This study is among the first to examine the effect of introducing nighttime and passenger restrictions to older novice teen drivers. The researchers were able to obtain both licensing and crash data from the state of Indiana. This allowed a careful analysis of the effect of the restrictions on those individuals known to be subject to the requirements. Previous analyses of such provisions have focused on age groups to which they generally apply, with no information available about the licensing conditions of crash-involved drivers. In contrast, the current study was able to examine the effects of GDL restrictions on the target population of the updated GDL system: newly-licensed 18- to 20-year-old novice drivers in their first year of licensed driving not the entire population of all drivers who are 18 to 20 years old.

This study also has a number of notable limitations. First, the study only examined the effects of the updated GDL system in Indiana for a relatively short period of time. Effects of GDL policies tend to take a few years to emerge and stabilize, rather than appearing

quickly. A second complication in analyzing GDL effects results from the fact that the age at which individuals obtain a license is discretionary. Individuals who waited until age 18 or older to obtain a license prior to the GDL update may have been different, in important ways that influence crash rates, from those licensed at older ages after the new requirements were put into place. Third, the licensing data available for the study were time-based (covering 2012–2017) instead of person-based. Because of this factor, a large number of potentially-eligible drivers were excluded due to the researchers' inability to clearly know whether many of the drivers who were issued a license during the study period were novice drivers or experienced drivers who were renewing their license or drivers licensed previously in another state.

Finally, the ability to identify crashes involving prohibited passengers or driving times was greatly limited both by the inclusion of exemptions in the requirements and the absence of information about uninjured passengers in crashes.

## **Conclusions and future directions**

To conclude, it is not surprising that the updates to Indiana's GDL system for older novices produced little of the intended benefit, as the largest effects of GDL tend to result from the lengthy learner period required of novice drivers prior to independent driving, which Indiana had already put into place prior to the updates to the GDL system that were the focus of the current study. Moreover, the newly added protections during nighttime driving and when carrying passengers involved several exemptions that limited their potential benefits. It will be important for researchers to examine the effects of extending GDL requirements to older novices in other states. This would be especially valuable when a full GDL system—including a sufficiently lengthy learner period—is extended to cover 18- to 20-year-old novice drivers.

In addition, although there has been limited research on the crash rates of older novice drivers, little is known about their travel needs and patterns. Such information is important to inform the design of licensing policies that will address the risks specific to this age group, and to ensure that GDL requirements are complied with so they produce the intended safety benefit.

Despite not finding evidence of safety benefits associated with the updated Indiana licensing system for older novice drivers, the current findings do provide valuable information for researchers and policymakers.

The lesson for legislators in other states, as well as the advocacy community, is that merely extending elements of a system designed for young novice teen drivers to older novices does not guarantee success. Moreover, adding exemptions to key elements presumed to be inconvenient to older novices is unlikely to increase travel safety for these individuals. To be effective, a GDL system for older novices will need to be designed with greater attention to the risks to, and needs of, older novice drivers.

## References

---

- Center for Disease Control and Prevention (CDC). Web-based injury statistics query and reporting system (WISQARS). 2017. <https://www.cdc.gov/injury/wisqars/>. Accessed 4/29/2019.
- Chapman, E. A., Masten, S. V., Browning, K. K. (2014). Crash and traffic violation rates before and after licensure for novice California drivers subject to different driver licensing requirements. *Journal of Safety Research*, 50, 125-138.
- Curry, A. E., Foss, R. D., & Williams, A. F. (2017). Graduated driver licensing for older novice drivers: Critical analysis of the issues. *American Journal of Preventive Medicine*, 6, 923-927.
- Curry, A. E., Metzger, K. B., Williams, A. F., & Tefft, B. C. (2017). Comparison of older and younger novice driver crash rates: Informing the need for extended Graduated Driver Licensing restrictions. *Accident Analysis and Prevention*, 108, 66-73.
- Curry, A. E., Pfeiffer, M. R., Durbin, D. R., & Elliott, M. R. (2015). Young Driver crash rates by licensing age, driving experience, and license phase. *Accident Analysis and Prevention*, 80, 243-250.
- Curry, A. E., Pfeiffer, M. R., & Elliott, M. R. (2017). Compliance with and enforcement of graduated driver licensing restrictions. *American journal of preventive medicine*, 52(1), 47-54.
- Foss, R. D. (2007). Improving graduated driver licensing systems: A conceptual approach and its implications. *Journal of Safety Research*, 38, 185-192.
- Foss, R. D. & Goodwin, A. (2003). Enhancing the effectiveness of graduated driver licensing on 16-year-old driver crashes in North Carolina. *The Journal of the American Medical Association*, 286, 1588-1592.
- Foss, R. D., Martell, C. A., Goodwin, A. H., & O'Brien, N. P. (2011). Measuring changes in teenage driver crash characteristics during the early months of driving. AAA Foundation for Traffic Safety. <https://aaaafoundation.org/measuring-changes-teenage-driver-crash-characteristics-early-months-driving>. Accessed 4/29/2019.
- Foss, R., Masten, S. & Martell, C. (2014). Examining the Safety Implications of Later Licensure: Crash Rates of Older vs. Younger Novice Drivers Before and After Graduated Driver Licensing. AAA Foundation for Traffic Safety.
- Governors Highway Safety Association (GHSA, 2018). 2018-2019 Policies and Priorities. <https://www.ghsa.org/sites/default/files/2018-09/policies18.pdf>. Accessed 4/29/2019.
- Hardin, J. W. & Hilbe, J. M. (2013). *Generalized estimating equations* (2<sup>nd</sup> ed.). Boca Raton, FL: CRC Press.
- Insurance Institute for Highway Safety (2017). Teenagers: Driving carries extra risk for them. <https://www.iihs.org/iihs/topics/t/teenagers/fatalityfacts/teenagers>. Accessed 4/29/2019.

- Lee, T. K., Wickrama, K. A.S., O'Neal, C. W., & Prado, G. (2018). Identifying diverse life transition patterns from adolescence to young adulthood: The influence of early socioeconomic context. *Social Science Research*, 70, 212-228.
- Lewis-Evans, B. (2010). Crash involvement during different phases of the New Zealand Graduated Driver Licensing System (GDLS). *Journal of Safety Research*, 41, 359-365.
- Liang, K, Zeger, S. L. (1986). Longitudinal data analysis using generalized linear models. *Biometrika*, 73, 13-22.
- Masten, S. V., & Foss, R. D. (2010). Long-term effect of the North Carolina graduated driver licensing system on licensed driver crash incidence: A 5-year survival analysis. *Accident Analysis and Prevention*, 42, 1647-1652.
- Masten, S. V., Foss, R. D., & Marshall, S. W. (2013). Graduated driver licensing program component calibrations and their association with fatal crash involvement. *Accident Analysis and Prevention*, 57, 105-113.
- Mayhew, D. R., Simpson, M., & Pak, A. (2003). Changes in collision rates among novice drivers during the first months of driving. *Accident Analysis and Prevention*, 35, 683-691.
- McCartt, A. T., Mayhew, D. R., Braitman, K. A., Ferguson, S. A., & Simpson, H. M. (2009). Effects of age and experience on young driver crashes: Review of recent literature. *Traffic Injury Prevention*, 10, 209-219.
- McKnight, A. J. & McKnight, A. S. (2003). Young novice drivers: Careless or clueless? *Accident Analysis and Prevention*, 35, 921-925.
- Ouimet, M. C., Pradhan, A. K., Brooks-Russell, A., Ehsani, J. P., Berbiche, D., & Simons-Morton, B. G. (2015). Young drivers and their passengers: a systematic review of epidemiological studies on crash rates. *Journal of Adolescent Health*, 57(1), S24-S35.
- Senserrick, T.M. & Williams, A.F. (2015). Summary of Literature of the Effective Components of Graduated Driver Licensing Systems. Austroads Ltd. Sydney NSW 2000 Australia Available at: <http://www.austroads.com.au> Accessed 5/9/2019.
- Shope, J. T. (2007). Graduated driver licensing: Review of evaluation results since 2002. *Journal of Safety Research*, 38, 165-175.
- Shults, R. A. & Williams, A. F. (2017). Trends in teen driver licensure, driving patterns, and crash involvement in the United States, 2006-2015. *Journal of Safety Research*, 62, 181-184.
- Tefft, B. C., Williams, A. F., & Grabowski, J. G. (2013). Teen driver risk in relation to age and number of passengers, United States, 2007–2010. *Traffic injury prevention*, 14(3), 283-292.
- Tefft, B. C., Williams, A. F., & Grabowski, J. G. (2014). Driver licensing and reasons for delaying licensure among young adults ages 18-20, United States, 2012. *Injury Epidemiology*, 1, 1-8.



Waller, P. F. (2003). The genesis of GDL. *Journal of Safety Research*, 34, 17-23.

Williams, A. F. (2017). Graduated driver licensing (GDL) in the United States in 2016: A literature review and commentary. *Journal of Safety Research*, 63, 29-41.

Williams, A. F. & Shults, R. A. (2010). Graduated driver licensing research, 2007-present: A review and commentary. *Journal of Safety Research*, 41, 77-84.

Williams, A. F., Tefft, B. C., & Grabowski, J. G. (2012). Graduated driver licensing research, 2010-present. *Journal of Safety Research*, 43, 195-203.

**Appendix A. Parameter estimates from the Poisson regression model of crash rates over the first 12 months of licensure**

---

Parameter	Estimate	Standard Error	p
Intercept	-3.76	0.19	<.001
Licensing system (updated)	0.12	0.04	0.00
Month	-0.06	0.00	<.001
Gas price	-0.04	0.03	0.15
25-34 crash rate	0.00	0.00	0.42
License age (19)	-0.56	0.32	0.08
License age (20)	0.00	0.39	0.99
Licensing system x license age (19)	0.03	0.06	0.60
Licensing system x license age (20)	-0.19	0.08	0.01
Gas price x license age (19)	0.04	0.05	0.48
Gas price x license age (20)	-0.13	0.06	0.03
25-34 crash rate x license age (19)	0.00	0.00	0.09
25-34 crash rate x license age (20)	0.00	0.00	0.31

**Appendix B. Parameter estimates of Poisson regression model predicting nighttime crash rate over the first 6 months of licensure**

---

Parameter	Estimate	Standard Error	p
Intercept	-5.85	0.54	<.001
Licensing system (updated)	0.22	0.10	0.03
Month	-0.04	0.01	<.001
Gas price	0.04	0.09	0.68
25-34 crash rate	0.00	0.00	0.46
License age (19)	-0.52	0.83	0.53
License age (20)	1.00	1.23	0.41
Licensing system x license age (19)	0.10	0.17	0.56
Licensing system x license age (20)	-0.61	0.23	0.01
Gas price x license age (19)	0.01	0.14	0.93
Gas price x license age (20)	-0.39	0.18	0.03
25-34 crash rate x license age (19)	0.00	0.00	0.41
25-34 crash rate x license age (20)	0.00	0.00	0.93

**Appendix C. Parameter estimates of Poisson regression model predicting multi-occupant crash rate over the first 6 months of licensure**

---

Parameter	Estimate	Standard Error	p
Intercept	-3.41	0.50	<.001
Licensing system (updated)	0.08	0.10	0.45
Month	-0.09	0.01	<.001
Gas price	-0.18	0.08	0.02
25-34 crash rate	0.00	0.00	0.03
License age (19)	-1.05	0.84	0.21
License age (20)	-0.59	1.07	0.58
Licensing system x license age (19)	0.04	0.18	0.82
Licensing system x license age (20)	-0.16	0.23	0.49
Gas price x license age (19)	0.18	0.13	0.18
Gas price x license age (20)	0.02	0.16	0.92
25-34 crash rate x license age (19)	0.00	0.00	0.42
25-34 crash rate x license age (20)	0.00	0.00	0.49