#419 Effect of Drivers Education on Traffic Safety

PI: Erick Guerra (0000-0002-7769-2581)

Co-PI: Xiaoxia Dong (0000-0002-3907-3237)

Final Report – July 31, 2025

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated in the interest of information exchange. The report is funded, partially or entirely, under [grant number 69A3552344811 / 69A3552348316] from the U.S. Department of Transportation's University Transportation

Centers Program. The U.S. Government assumes no liability for the contents or use thereof.

Technical Report Documentation Page

<table>
<tr><td>1. Report No.

419</td><td>2. Government Accession No.</td><td>3. Recipient’s Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle

Effect of Drivers Education on Traffic Safety: GDL-Mandated Comprehensive Driver Training Reduces Young Novice Drivers’ Involvement in Seriously Injurious and Fatal Crashes</td><td>5. Report Date

July 23, 2025. Paper to be submitted to the Transportation Research Board for presentation and publication by August 1, 2025.</td></tr>
<tr><td>6. Performing Organization Code

Enter any/all unique numbers assigned to the performing organization, if applicable.</td></tr>
<tr><td colspan="2">7. Author(s)

Xiaoxia Dong, Ph.D., https://orcid.org/0000-0002-3907-3237;

Jasmine Siyu Wu, https://orcid.org/0000-0002-3855-4872;

Erick Guerra, Ph.D., https://orcid.org/0000-0002-7769-2581;

Megan S. Ryerson, Ph.D., https://orcid.org/0000-0002-8843-3286;

Elizabeth A. Walshe, Ph.D., https://orcid.org/0000-0002-0466-4272</td><td>8. Performing Organization Report No.

Enter any/all unique alphanumeric report numbers assigned by the performing organization, if applicable.</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address

The University of Pennsylvania
Weitzman School of Design
210 S. 34th St.
Philadelphia, PA 19104</td><td>10. Work Unit No.</td></tr>
<tr><td>11. Contract or Grant No.

Federal Grant # 69A3552344811 / 69A3552348316</td></tr>
</table>

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Enter name and address of the organization(s) financially responsible for the work. After each agency name, enter funding type (e.g. SPR). Example: Missouri Department of Transportation (SPR)	Final Report (July 1, 2024 – June 30, 2025)
	14. Sponsoring Agency Code USDOT

15. Supplementary Notes

Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

Enter information not included elsewhere, such as translation of (or by), report supersedes, old edition number, alternate title (e.g. project name), hypertext links to documents or related information in the form of URLs, PURLs (preferred over URLs - https://archive.org/services/purl/help), DOIs (https://www.doi.org/), insertion of QR codes, copyright or disclaimer statements, etc. Edit boilerplate FHWA statement above if needed.

16. Abstract

Despite nationwide GDL laws, young driver crashes remain disproportionately high. Some states with additional GDL-mandated driver training show reduced crash rates in young new drivers, but the impact on crash severity is not known. We used a Chi-square analysis and a binomial logit analysis to examine whether and how comprehensive driver's education and training requirements under GDL laws are associated with involvement in severe crashes one year after licensure among young novice drivers. Data came from a partnership between the Children's Hospital of Philadelphia and the Ohio Traffic Safety Office, -including licensing and crash records of over 130,000 novice drivers first licensed under age 25 between 2017 and 2019. We found significant associations between GDL-mandated driver training completion and severe crash involvement among young novice drivers. On average, drivers who completed GDL-mandated driver training had approximately 70% lower odds of being involved in severe crashes one year after licensure than those who did not. Our findings remind officials about the urgency to allow teens access to GDL-required training to reduce severe crashes immediately post-licensure.

17. Key Words	18. Distribution Statement
Binomial logit regression, Chi-square test, Driver training, Graduated driver licensing, Young novice drivers, Severe crashes	No restrictions. This document is available through the National Technical Information Service, Springfield, VA 22161. Enter any other agency mandated distribution statements. Remove NTIS statement if it does not apply.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified.	Unclassified.	17	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

GDL-Mandated Comprehensive Driver Training Reduces Young Novice Drivers' Involvement in Seriously Injurious and Fatal Crashes

Xiaoxia Dong, Ph.D. (https://orcid.org/0000-0002-3907-3237)

Jasmine Siyu Wu (https://orcid.org/0000-0002-3855-4872)

Erick Guerra, Ph.D. (https://orcid.org/0000-0002-7769-2581)

Megan S. Ryerson, Ph.D. (https://orcid.org/0000-0002-8843-3286)

Elizabeth A. Walshe, Ph.D. (https://orcid.org/0000-0002-0466-4272)

FINAL RESEARCH REPORT – July 31, 2025

Introduction

Car crashes are one of the leading causes of deaths among young people in the U.S. Young drivers are disproportionately involved in crashes, and crash risk is highest in the months immediately following licensure (before falling to adult levels between 1-2 years after license). Young Novice drivers are especially vulnerable to crashes due to inexperience, lack of driving skills, immaturity, among other factors (*1–4*). All 50 U.S. states have implemented Graduated Driver Licensing (GDL) laws as the national strategy to reduce crashes, but young driver crashes remain high. While GDL laws generally require teens to practice driving with supervision before getting their junior licenses, also known as probationary licenses, and restrict driving after they are licensed, specific requirements vary by state with mixed effects (*5*). Ohio, for example, requires teens under age 18 years to complete 24 hours of classroom or online instruction and 8 hours of behind-the-wheel (BTW) professional driver training, in addition to 50 hours of supervised practice (*6*). Meanwhile, Mississippi requires no driver's education course or instructed driving at a driving school.

Our prior work in Ohio has shown that young novice drivers who completed comprehensive driver training requirements under GDL laws have lower crash rates immediately after licensure than those aged out of GDL (those age 18, who had the highest crash rates of all new drivers under age 25 years) (*7–9*). Similar GDL requirements and associated crash trends have been observed in California (*10*). However, not all crashes are equal. Severe crashes that result in serious injuries and deaths exact a heavy toll on the victims and society. Furthermore, severe crashes disproportionately affect young novice drivers (*11*, *12*). While researchers have identified socioeconomic, built environment, and behavioral factors that contribute to severe crashes, including those that involve young drivers (*13–15*), few have examined the relationship between GDL-mandated driver education and driver training and severe crash outcomes. An understanding of the relationship between GDL-mandated driver training and severe crashes is a critical first step towards addressing an urgent transportation and public health issue. For example, if GDL-mandated driver training is evidenced to reduce severe crashes among young novice drivers early in licensure, then it would be crucial for policymakers to improve access to GDL-mandated driver training to enhance safety for all road users.

In this paper, we address this gap by examining whether and how comprehensive driver's education and training requirements under GDL laws are associated with involvement in severe crashes one year after licensure among young novice drivers. We restrict the crash observation period to one year after licensure to ensure that the drivers were novices. We hypothesize that young novice drivers who completed GDL-mandated driver training before time of licensure (i.e. those <18 years of age) are less likely to be involved in severe crashes than those who did not complete GDL-mandated driver training (i.e. those ages 18 to 24). We use the Chi-square test and the binomial logit model to examine a unique dataset of linked driver licensing and crash records of over 130,000 novice drivers in Ohio between 2017 and 2019.

Our study makes three contributions. First, it provides evidence for the effectiveness of GDL-mandated driver training in reducing severe crashes early in licensure and thus informs states' efforts to enhance young driver safety. Second, so far, the literature on this topic has mainly been concerned with total crashes due to data limitations. Our study furthers the literature by focusing on severe crashes. Third, the study found patterns in the timing of obtaining a driver's license among young novice drivers. These patterns present rich opportunities for future research.

Literature Review

Motor vehicle crashes remain one of the leading causes of death for adolescents and young adults in the U.S. (*16*, *17*). Drivers 16 to 19 years old averaged only half the national average miles driven across all age groups, but had three times higher fatal crash rate per mile driven than older drivers (*18*, *19*). Notably, the majority of fatalities among 16- to 19-year-old passenger vehicle occupants occurred in vehicles driven by teenagers themselves, underscoring the acute safety challenges faced by young novice drivers (*18*). Young novice drivers, particularly those under 25, are at heightened risk due to limited driving experience, developmental factors, and increased exposure to risky behaviors (*1*, *3*, *4*, *20*). This risk is particularly elevated during the first months following licensure (*21*, *22*).

In an attempt to reduce young driver crashes, all 50 U.S. states have implemented GDL systems, which introduce driving privileges in phases and commonly include requirements such as supervised practice and sometimes formal driver education. As of 2023, 31 states mandate behind-the-wheel (BTW) training with certified instructors, and 41 states require adult-supervised practice for license applicants under 18 (*23*). While the effectiveness of driver training has long been debated (*5*, *24*, *25*), more recent research highlights the synergistic benefits of comprehensive GDL systems that incorporate driver training in improving skill acquisition and reducing crash risks (*7*, *10*, *26*, *27*). In Ohio, for instance, teen drivers who completed GDL-mandated training demonstrated higher on-road exam pass rates (*7*), performed better in specific new driving skill domains (*28*), and had lower crash rates drivers licensed at age 18 years who were not beholden to GDL (*7*). While much of the existing literature focuses on overall crash incidence, less attention has been paid to severe crashes. From a public health standpoint, these events pose the greatest burden on individuals, families, and healthcare systems, and thus warrant focused prevention efforts.

Although existing studies have established links between GDL, driver training, and crash involvement, few have disaggregated crash severity or systematically examined subgroups defined by training status, age at licensure, and neighborhood context. In particular, the difference between those in Ohio driving under GDL with mandated training and with an probationary license before age 18 and those age 18 who are outside of GDL requirements and driving with an unrestricted adult license represents a key policy threshold that remains underexplored. This age-based distinction may have important implications for training uptake

and subsequent crash outcomes. By focusing specifically on severe crashes occurring within one year of licensure, and by linking a large administrative dataset to examine how age, comprehensive licensing laws, and geography interact to shape crash risks among young novice drivers, this study contributes new insights into the public health implications of licensing policies.

Study Context and Conceptual Framework

Study area

We focus on the State of Ohio for three main reasons. First, the close partnership of our research team with the Ohio Traffic Safety Office has allowed us to access extensive licensing data for Ohio drivers and link the licensing data with traffic crash data. Second, Ohio's comprehensive GDL laws require teens under 18 to complete BTW driver training with a paid, certified instructor to receive a probationary license, where many other states do not (*23*). Thus, Ohio's GDL laws provide an opportunity for a natural experiment to study the effect of comprehensive GDL requirements that include driver education and BTW training on severe crash risks. Third, Ohio encompasses a wide range of typologies, including dense urban areas (e.g., Cleveland and Columbus), suburban areas, and rural areas. This diverse context makes Ohio an interesting study area for investigating how the relationship between GDL-mandated driver training and involvement in severe crashes may vary across geographies. States with similar typological mixes might also find our findings relevant to their local contexts.

Ohio GDL laws

In the state of Ohio, individuals under 18 follow a GDL system—a three-stage process designed to ease novice drivers increasing levels of driving responsibility. The process begins with a Temporary Instruction Permit Identification Card (TIPIC), which teens may obtain at age 15.5 after passing a written knowledge test and vision screening. The TIPIC is valid for one year, during which teens must hold the permit for at least six months and complete key training requirements before taking the licensing on-road exam: 24 hours of classroom education, 8 hours of behind-the-wheel BTW instruction, and 50 hours of supervised driving (including 10 hours at night) with a parent or guardian.

After meeting these requirements and passing the ORE, teens are issued a probationary license, which imposes restrictions on driving (e.g. no nighttime driving, a limited number of passengers) to reduce crash risk. Only at 18 do drivers become eligible for a full, unrestricted license, assuming a clean record.

For the purposes of this analysis, we refer to licensure before age 18 as obtaining a *probationary* license under the GDL system, which requires mandatory driver education and BTW training, and imposes driving restrictions. Licensure at or after age 18 corresponds to a *full*, unrestricted adult license, for which Ohio law does not require GDL or BTW training. However, applicants

ages 18 and above who fail the on-road exam must complete an abbreviated adult driver education course before attempting the ORE again. This abbreviated education course is most often an online knowledge course.

Analysis roadmap

We conducted two statistical analyses to examine whether and how comprehensive driver's education and training requirements under GDL laws are associated with involvement in severe crashes one year after licensure among young novice drivers. We summarize the analysis methods here before delving into details of the data, driver groups, and the statistical analyses in the following sections. In the first analysis, we used Pearson's Chi-square test to examine the association between a binary severe crash variable that indicates whether a driver was involved in a severe crash one year after licensure and four driver groups based on the driver's completion of GDL-mandated driver training and licensing pathway. To better understand the effect of GDL-mandated driver training on involvement in severe crashes, in the second analysis, we used the binomial logit regression model to test how involvement in severe crashes differs between drivers who completed GDL-mandated driver training before obtaining a driver's license and those who did not.

Methods

Chi-square test

We used the Chi-square test to examine the association between the categorical variables of driver groups (4, varying by GDL completion) and involvement in severe crashes (binary) in the first year of licensure. We explain the data and variables in greater detail in the Data section below. The Chi-square test was conducted using the gmodels package in R (*29*).

Binomial logit regression

We also used the binomial logit model to test the hypothesis that young novice drivers who completed GDL-mandated driver training before time of licensure (i.e. those <18 years of age) are less likely to be involved in severe crashes than those who did not complete GDL-mandated driver training (i.e. those age 18 and above).

There were fewer than 100 drivers in the dataset (n = 133,273) who were involved in severe crashes one year after licensure. To correct for potential small sample bias, we also estimated Firth's penalized logistic regression. The output was comparable to that from the regular binomial logit models. For simplicity, we reported the output from the regular binomial logit models. Binomial logit models were estimated in R.

Data

Licensing and crash data

This study utilizes Ohio's administrative Bureau of Motor Vehicles (BMV) licensing database and police-reported crash database from January 2017 to December 2019, obtained through an agreement between the Ohio Department of Public Safety and the Children's Hospital of Philadelphia (CHOP). A data operations team at the Children's Hospital of Philadelphia prepared deidentified data tables in accordance with data privacy agreements between Ohio and CHOP (see (*7*) for more detail). All personally identifiable and locational information was removed prior to researcher access. Figure 1 illustrates the multi-source data integration process used to construct the analytic dataset.

Licensing tables included each driver's de-identified customer identifier, sex (male/female), permit and licensure dates (converted to age in days), driver training completion age (in days), ORE results and age (in days). To classify drivers into licensing pathway subgroups, we constructed derived variables indicating age at first permit and first license (in days), pass/fail outcome on the first ORE attempt, and a binary indicator of whether the driver completed driver training prior to licensure.

Crash records included hierarchical data at the crash-, unit-, and person-levels, with nested identifiers allowing linkage across levels. We extracted and processed the person-level files, retaining only records for individuals marked as "drivers" and matched to licensing records through the de-identified customer identifiers. Key variables included crash severity, driver gender, and exact age (in days) at the time of the crash. Crashes were filtered to retain only fatal and serious injury crashes that occurred within 365 days of each individual's first licensure date, ensuring a consistent post-licensure exposure window. Fatal and serious injury crashes were identified using the field "crash severity" in the traffic crash report data. According to the Ohio Department of Public Safety's definitions (*30*), a fatal crash in the crash record was one in which at least one person died within 30 days of the incident, and a serious injury crash—also referred to as "suspected serious injury"—was any non-fatal injury that prevents the person from walking, driving, or performing activities they were capable of before the crash, such as broken limbs, unconsciousness, severe lacerations, or hospitalization.

We then merged the de-identified licensing and crash datasets using the deidentified customer identifiers, resulting in an integrated longitudinal dataset of 133,273 unique novice under-25 drivers who could be categorized into one of the four defined licensing subgroups (see Driver Groups section). We identified and counted all serious injury and fatal crashes within one year post first licensure using age variables. For drivers who did not appear in the crash data, we inferred the absence of a recorded serious or fatal crash within the observation period (2017-19). Because of the low incidence of such crashes, we combined serious injury and fatal crash events into a single binary outcome variable indicating whether a driver was involved in one or more severe crashes during the first year of independent driving.

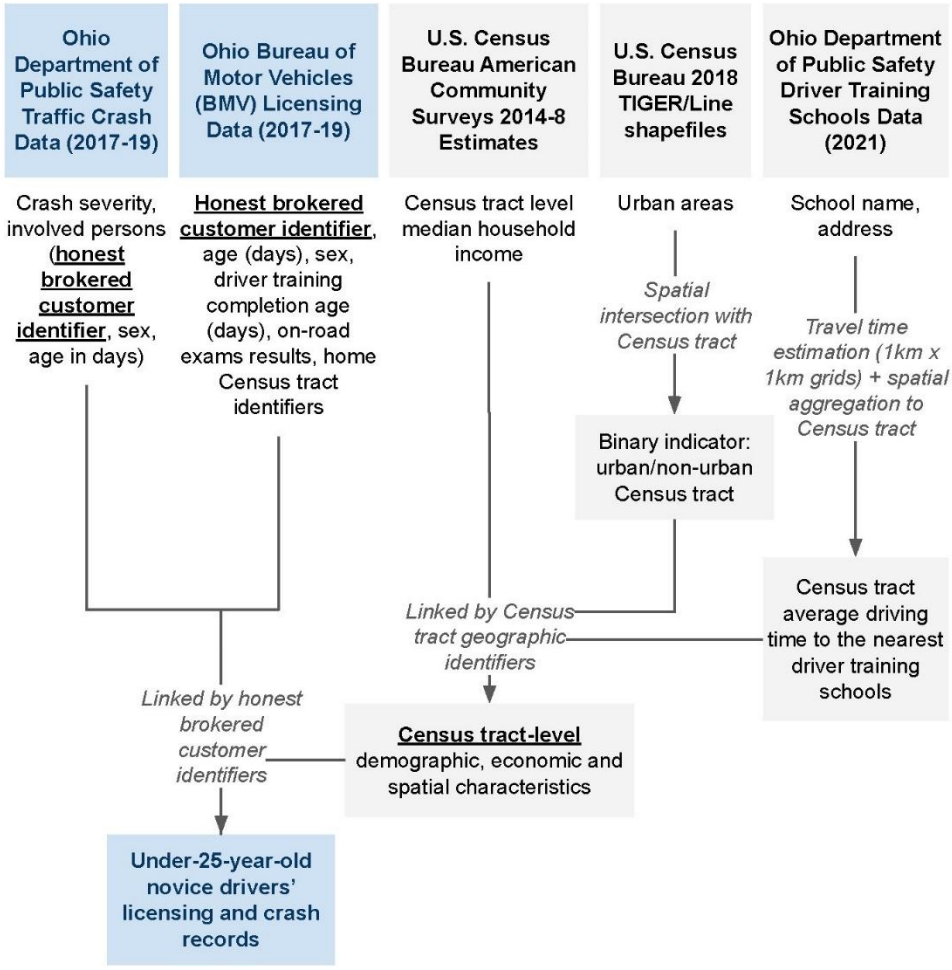

Figure 1 Data integration and variable construction

Driver groups

The legal distinctions between GDL-based probationary licensure and unrestricted adult licensure form the basis for our subgroup classifications and underscore the relevance of age-specific policies in shaping young driver behavior and crash risk. For the Chi-square test, we categorized the drivers into four groups based on drivers' ORE records, GDL-mandated driver training completion status, and age of receiving a driver's license. The classification ensured that drivers' licensing pathways were comparable within each group and distinct across groups. Figure 2 shows the categorization process of the driver groups. The four driver groups are described as follows.

- *Group A (N = 72,024):* Drivers completed the GDL-mandated driver training for teens, passed the on-road exam on the first attempt, received probationary licenses, and were subject to GDL driving restrictions post-licensure until they turned 18 (*31*)

- *Group B (N = 22,285):* Drivers completed the GDL-mandated driver training for teens but failed the on-road exam on the first attempt. They passed the exam later either before or after turning 18. Compared to the other groups, the sample size of those in Group B who received licenses after turning 18 is very small (N = 780). Thus, we decided not to further split Group B into two distinct groups by their age of licensure.
- *Group C (N = 23,977):* Drivers did not take the GDL-mandated driver training and took the ORE for full licensure after 18 years old (including those who received their first permit slightly before 18 to initiate the licensing process). They passed the ORE on the first attempt and had no GDL restrictions on driving post-licensure.
- *Group D (N = 14,898):* Drivers did not take the GDL-mandated driver training and took the ORE for full license after 18 years old (including those who received their first permit slightly before 18 to initiate the licensing process). They did not pass the ORE on the first attempt, took the abbreviated driver education as required, and passed the ORE at later attempts. They did not have any GDL restrictions on driving post-licensure.

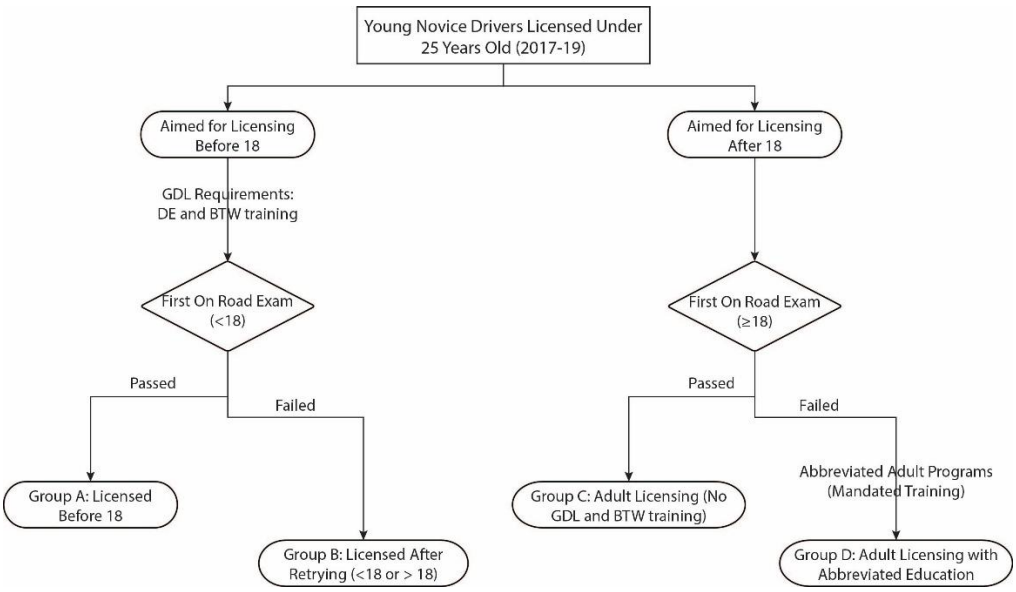

Figure 2 Workflow of driver group classification

For the binomial logit analysis, we reclassified the drivers into two groups based on their GDL-mandated driver training completion, ORE records, and timing of obtaining a temporary permit and a driver's license. As explained above, Ohio's GDL laws require teens to hold a temporary permit for at least 6 months before taking the ORE and obtaining a probationary license. While adults over 18 are required to obtain a temporary permit before taking the ORE, they are not subject to any permit-holding period requirements (e.g. they can obtain the permit and attempt the ORE on the same day). The different requirements by age mean that drivers under 18 could have greater exposure to driving under GDL laws before obtaining a license than those who are over 18 and not under restriction. The uneven exposure as a result of the permit-holding requirement and restricted driving requirements for teens could confound the effect of GDL-

mandated driver training on severe crash risks post-licensure. However, we do not have access to exposure data to incorporate into this study. To ensure comparable exposure in the permit period, we reclassified the drivers into two groups:

- *Driver Training Group (N = 72,024):* This group is identical to Group A above. It includes drivers who completed the GDL-mandated driver training, passed the on-road exam on the first attempt, received probationary licenses, and were subject to GDL driving restrictions post-licensure until they turn 18.
- *No Training Group (N = 1,825):* This group is a subset of Group C above. Drivers received temporary permits between the ages 17 and 17.5, did not complete GDL-mandated driver training, took the ORE for full licensure after 18 years old, passed the ORE on the first attempt, and received driver's license between the ages 18 and 18.5.

Thus, the classification helps to control for exposure to driving in the learner permit. Drivers in the two groups were also comparable in terms of passing the ORE on the first attempt. We used this grouping in the binomial logit analysis to more effectively parse out the impact of GDL-mandated driver training on involvement in severe crashes.

Neighborhood characteristics

We integrated neighborhood-level characteristics to account for contextual factors that may influence individual licensing pathways and crash outcomes. Prior research has shown that both financial and spatial barriers to driver training are associated with lower rates of GDL participation among young drivers (*32–34*). Incorporating these contextual layers supports a more comprehensive understanding of the structural and spatial factors that shape teen driver safety and mobility.

Ohio BMV data included home address at the time of licensure. In accordance with data privacy protocols, the CHOP data operations team geocoded these addresses and spatially joined them to Census tract boundaries using the 2018 TIGER/Line shapefiles from the Census Bureau (Figure 1). All personally identifiable and locational information was removed prior to researcher access to ensure confidentiality.

Using the Census tract geographic identifiers, we linked each driver to neighborhood-level data from the 2018 American Community Survey 5-Year Estimates. Key variables included median household income and an urban-rural classification based on whether the tract intersected a Census–defined urbanized area. These variables served as proxies for individual economic and environmental context, allowing us to explore how neighborhood-level conditions might be associated with young drivers' licensing pathways and crash outcomes.

To assess spatial accessibility to driver training, we created a geographic measure of travel time to the nearest certified training provider, following methodologies established in prior research (*34*, *35*). First, we retrieved provider names and locations from the Ohio Department of Public Safety's public directory as of December 2021 (*36*) and geocoded the addresses using the Google

Maps Platform APIs. We used the ***R5r*** package in R (*37*), an open-source routing package, to estimate realistic driving times from all Ohio Census tracts to the nearest provider.

RESULTS

Sample Characteristics

Table 1 shows the summary statistics of drivers' sex and their home Census tracts' socioeconomic conditions by driver group. A subset of young drivers (N = 10,803; 8.1%) lacked valid Census tract identifiers due to missing or unmatchable geocoded address data, which prevented the assignment of spatial and economic context. A Wald test indicates that the availability of tract-level information is not significantly associated with involvement in severe crashes, reducing concern about potential selection bias. The proportion of drivers missing tract data is similar across groups (5.8-8.8%). In each driver group, most drivers lived in urban Census tracts. Drivers who completed GDL-mandated driver training appear to be more likely to reside in higher income Census tracts (Groups A and B) (*32*, *34*).

Table 1 Driver characteristics by driver group

Group	Variable	Percentage	Mean	Maximum	Minimum	Standard Deviation
A	Male	50.88				
	Female	49.12				
	Urban	90.42				
	Non-urban	9.58				
	Median household income (dollars)		71,884	250,001	7,980	29,938
	Mean travel time to nearest driving school (minutes)		9.53	69.1	2.05	5.12
B	Male	46.59				
	Female	53.41				
	Urban	92.18				
	Non-urban	7.82				
	Median household income (dollars)		70,919	250,001	8,333	30,291
	Mean travel time to nearest driving school (minutes)		9.04	69.1	2.05	4.78
C	Male	55.51				
	Female	44.49				
	Urban	94.59				
	Non-urban	5.41				
	Median household income (dollars)		50,673	191,125	3,998	23,001
	Mean travel time to nearest driving school (minutes)		8.8	69.1	2.05	4.78
D	Male	50.21				

	Female	49.79				
	Urban	96.23				
	Non-urban	3.77				
	Median household income (dollars)		49,874	250,001	3,998	23,555
	Mean travel time to nearest driving school (minutes)		8.31	38.6	2.05	4.19

In Figure 3, we plotted the time points of when drivers obtained their first leaner permit and first license across age groups, to illustrate how drivers under age 18 have longer minimum learner permit holding periods, whereas drivers over age 18 can obtain both permit and licensing in a short period of time (sometimes the same day).

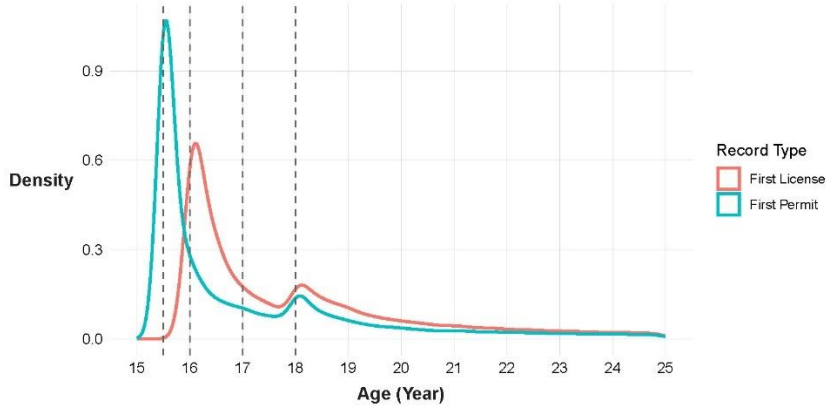

Figure 3 Age of obtaining first temporary permit and first driver's license

Association between involvement in severe crashes and GDL training

The Chi-square statistic ($X^2 = 226$, degree of freedom = 3) indicated that driver group and involvement in severe crashes were significantly associated ($p < 0.001$). The standardized residuals indicated that the overall association between driver groups and involvement in severe crashes was primarily driven by the lower-than-expected number of drivers who were involved in severe crashes in Groups A and B, and the higher-than-expected number of drivers who were involved in severe crashes in Groups C and D. In Groups A and B, 89 and 37 drivers were involved in severe crashes when 195 and 60 were expected, respectively (standardized residuals = -7.58 and -2.99, respectively). Meanwhile, in Groups C and D, 148 and 86 drivers were involved in severe crashes respectively when only 65 and 40 were expected (standardized residuals = 10.342 and 7.213, respectively). The analysis found no significant contribution from drivers that were not involved in severe crashes within each driver group.

Overall, the findings indicated that Groups A and B, whose drivers took GDL-mandated driver training, had significantly fewer-than-expected drivers with severe crashes post-licensure,

whereas Groups C and D, whose drivers did not take GDL-mandated driver training, had significantly more-than-expected drivers with severe crashes.

Effect of GDL-mandated training

We estimated two binomial logit regression models to test how involvement in severe crashes differ between the Driver Training Group and the No Training Group. In both models, the dependent variable was the binary indicator of involvement in a severe crash post-licensure. Model 1 included driver groups as the only independent variable. Model 2 included driver's sex, and the median household income, distance to driving school, and urban classification of the driver's home Census tract, in addition to driver groups. We converted median household income to the logarithm scale to facilitate the interpretation of the coefficient. We also tested the age when drivers received their first license. This variable was too closely related to driver group membership and was excluded from the reported models. Table 2 shows the output from the two binomial logit models. In both models, the reference category was drivers not involved in severe crashes.

Table 2 Output from binomial logit models

	Model 1	**Model 2**
Variable (reference category)		
	Coefficient (S.E.)	
Intercept	-5.353*** (0.354)	0.004 (2.978)
Driver group (No GDL training)		
GDL training	-1.333*** (0.371)	-1.193** (0.378)
Sex (Female)		
Male		0.348 (0.216)
Median household income (log)		-0.508 (0.268)
Travel time to nearest driving school (mins)		0.009 (0.021)
Urban area (No)		
Yes		-0.172 (0.364)
AIC	1,366.3	1,366.8
BIC	1,384.5	1,421.5
Log Likelihood	-681.1	-677.4

Both models indicated that drivers who completed GDL-mandated driver training at the time of licensure had significantly lower probabilities of being involved in severe crashes post-licensure. On average, drivers who completed GDL-mandated driver training had approximately 70% lower odds of being involved in severe crashes one year after licensure (the exponentiated coefficients for GDL training, -1.333 and -1.193, minus one). Hypothetically, older novice drivers who did not complete GDL-mandated driver training and have unrestricted licenses (i.e. possibly greater exposure to higher risk driving situations) likely have lower likelihood of crashing due to greater maturity than younger novice drivers without GDL-mandated driver

training. Thus, it is likely that the coefficients for GDL training underestimated the crash reduction effects of GDL-mandated driver training.

The median household income of the driver's home Census tract had a negative association with involvement in severe crashes. On average, each one percent increase in median household income corresponded to 0.5% lower odds of being involved in severe crashes one year post-licensure, all else being equal. This association is marginally significant.

Model 2 found no statistically significant associations between severe crash involvement and drivers' sex, travel time to the nearest driving school from the driver's home Census tract, and urban typology of the driver's home Census tract.

Model 1 that included only GDL training had a better fit than Model 2 with control variables, as indicated by Model 1's smaller AIC and BIC statistics. This finding confirmed that GDL training played a more significant role than individual drivers' sex and the neighborhood-level risk factors.

Discussion

Our findings reveal significant associations between involvement in severe crashes and whether young novice drivers completed GDL-mandated driver training. Among young drivers who completed GDL-mandated driver training, there were significantly fewer-than-expected drivers with severe crashes, regardless of whether the driver passed the ORE on the first attempt. Meanwhile, there were significantly more drivers than expected with severe crashes among young drivers who did not complete GDL-mandated driver training. These effects remained even when controlling for neighborhood-level factors.

Policy implications

Prior research has found that comprehensive GDL laws that mandate formal driver training in Ohio and California are associated with lower crash risks among young drivers without distinguishing crash severity (*7*, *10*). Our findings advance understanding by showing that GDL including mandated driver training was associated with less involvement in severe crashes early in licensure, when crash risk is highest (*7*). The results suggest that comprehensive GDL laws that include requirements for professional BTW training may reduce severe crashes and improve road safety. Currently, only 31 states in the U.S. mandate some form of formal BTW driver training for teen drivers before obtaining a probationary license. Furthermore, state-funded BTW training programs in schools have dwindled since the 1980s. While this study could not fully isolate the effect of BTW training from all other GDL features, it provides further evidence that training may be the most modifiable risk factor for young novice driver crashes.

One obstacle to studying driver training's effect on young driver crash risks is the uneven exposure to driving before obtaining a driver's license. Teen drivers are required by GDL laws to

hold a temporary permit for at least 6 months before obtaining a probationary license. Meanwhile, our data shows that most adults over 18 years old, who are no longer subject to the GDL program, took the on-road exam and obtained a driver's license shortly after obtaining a temporary permit (Figure 3). Our licensing data enabled us to select a subset of drivers with comparable exposure to driving pre-licensure. This advantage allowed us to more effectively isolate the effect of GDL-mandated driver training on reducing involvement in severe crashes than in prior work (*7*). Current work is underway to more rigorously examine the effect of BTW driver training on crash risk early in licensure, via a random assignment trial, conducted by CHOP in Pennsylvania.

Prior research has shown that some teens face financial and travel barriers to formal driver training and may even have to forgo employment and educational opportunities that are afforded by a driver's license (*32*, *34*). Our findings of GDL-mandated driver training's benefits to enhancing safety for young novice drivers provide further justification for policymakers in states that require mandatory driver training to design targeted interventions, such as financial assistance programs, to improve access to driver training. Furthermore, our findings from a state with comprehensive GDL policies should remind officials in states with less stringent GDL laws to examine their GDL programs' effectiveness in reducing severe crashes among young novice drivers and update the programs accordingly.

Research implications

Our study reveals several noteworthy patterns for further research when data becomes available. Firstly, completion of GDL-mandated driver training played a more significant role in young novice drivers' severe crash involvement than drivers' sex and their neighborhood-level risk factors. We tested additional models with only the control variables and found that median household income and sex were significantly and marginally correlated with severe crash involvement, respectively. That these variables became less significant with the inclusion of GDL-mandated driver training completion suggests that the effects of these risk factors might be mediated by GDL with mandated driver training. When possible, researchers should consider the impact of driver training in individual-level crash analysis as it could improve the explanatory power of models that only include drivers' individual characteristics.

Secondly, we observed in Figure 3 that some teens elected to obtain a temporary permit shortly before turning 18 and then obtain a regular driver's license after 18 before the permit expires. This licensing pathway would allow teens to drive under the restrictions of a temporary permit until they age out of GDL, thus forgoing GDL-mandated driver training before obtaining a full license. Future research should examine whether teens who follow this pathway face barriers to formal driver training, and the effect of this pathway on teen driver skill acquisition and crash risks.

Lastly, we observed that among drivers who completed GDL-mandated driver training, those who obtained their probationary driver's license between 16 and 17 had lower severe crash rates

than those who obtained their license between 17 and 18. Under Ohio's GDL laws, those who received probationary licenses between 16 and 17 would still be under driving restrictions during the one-year post-licensure crash observation window. Meanwhile, at least some of those who received probationary licenses between 17 and 18 would have aged out of GDL and were no longer under restrictions during the one-year post-licensure period. Due to data limitation, we were unable to determine how much of the difference in severe crash rates can be attributed to driving restrictions. When data becomes available, researchers should consider identifying factors that could contribute to the differences in severe crash risks between younger and older novice drivers.

Limitations

The current study has four limitations due to data availability. First, we used Census tract data as indirect measures of individual financial and environmental context conditions as the Ohio licensing data did not have direct measures of this. Relatedly, a subset of individuals lacked valid Census tract identifiers, preventing us from assigning spatial and economic characteristics, however this was a small percentage. Although we conducted statistical tests to evaluate potential selection bias, the possibility remains that missing tract data are associated with key outcomes such as crash involvement. Furthermore, Census tract characteristics were assigned based on the address at the time of licensure. We could not verify whether drivers moved after licensure. Second, taking GDL-mandated driver training before 18 is a personal choice. It is possible that at least some of the teens who chose to fulfill the GDL requirements and obtain early licensure were more safety conscious than those who decided to wait until 18 for licensure without GDL training. The current data does not allow us to investigate how safety awareness contributed to the different crash outcomes across age groups. Third, some exposure heterogeneity may exist within our defined subgroups due to the absence of licensing and crash year variables for privacy protection. Drivers' actual exposure to GDL restrictions likely varied depending on their specific age at licensure and the calendar year during which they entered the system. Without detailed timing data, we could not determine which drivers aged out of GDL restrictions during the crash observation window. Finally, while we measured crash involvement within one year post-licensure, we were unable to account for differences in driving frequency, mileage, vehicle access, or road conditions: to the best of our knowledge, no vehicle miles travelled exposure data is broken down in age groups smaller than 15-19 years.

Conclusion

Severe crashes among young novice drivers are an urgent public health issue. We find significant associations between the completion of comprehensive GDL laws that include driver training requirements and involvement in severe crashes among young novice drivers in the first year of licensure, when crash risk is highest. Young novice drivers who had completed GDL-mandated driver training at the time of licensure were less likely to be involved in severe crashes than those

who did not complete GDL-mandated driver training. Our findings serve as a reminder for officials that there should be more urgency to allow teens access to GDL-required driver education and training during their critical developmental period to reduce severe crashes immediately post-licensure.

References

1. Curry, A. E., K. B. Metzger, A. F. Williams, and B. C. Tefft. Comparison of Older and Younger Novice Driver Crash Rates: Informing the Need for Extended Graduated Driver Licensing Restrictions. *Accident; Analysis and Prevention*, Vol. 108, 2017, pp. 66–73. https://doi.org/10.1016/j.aap.2017.08.015.
2. Governors Highway Safety Association. Teens & Novice Drivers. https://www.ghsa.org/state-laws-issues/teens-novice-drivers. Accessed Jul. 17, 2025.
3. Simons-Morton, B., N. Lerner, and J. Singer. The Observed Effects of Teenage Passengers on the Risky Driving Behavior of Teenage Drivers. *Accident Analysis & Prevention*, Vol. 37, No. 6, 2005, pp. 973–982. https://doi.org/10.1016/j.aap.2005.04.014.
4. Romer, D., Y.-C. Lee, C. C. McDonald, and F. K. Winston. Adolescence, Attention Allocation, and Driving Safety. *Journal of Adolescent Health*, Vol. 54, No. 5, 2014, pp. S6–S15. https://doi.org/10.1016/j.jadohealth.2013.10.202.
5. Mayhew, D. R., H. M. Simpson, A. F. Williams, and S. A. Ferguson. Effectiveness and Role of Driver Education and Training in a Graduated Licensing System. *Journal of Public Health Policy*, Vol. 19, No. 1, 1998, pp. 51–67.
6. Ohio Bureau of Motor Vehicles. Temporary Permit / Probationary Driver Licensing – Under Age 18. https://www.bmv.ohio.gov/dl-gdl.aspx. Accessed Jul. 17, 2025.
7. Walshe, E. A., D. Romer, A. J. Wyner, S. Cheng, M. R. Elliott, R. Zhang, A. K. Gonzalez, N. Oppenheimer, and F. K. Winston. Licensing Examination and Crash Outcomes Postlicensure in Young Drivers. *JAMA Network Open*, Vol. 5, No. 4, 2022, p. e228780. https://doi.org/10.1001/jamanetworkopen.2022.8780.
8. Wu, J. S., X. Dong, E. A. Walshe, F. K. Winston, and M. S. Ryerson. The Association Between Young New Drivers' Skills and Driver Training, with Home Neighborhood Income Level, and Urbanicity: Evidence from the State of Ohio. *Transportation Research Record*, In progress.
9. Walshe, E. A., M. R. Elliott, S. Cheng, D. Romer, A. E. Curry, D. Grethlein, A. K. Gonzalez, and F. K. Winston. Driving Skills at Licensure Predict Time to First Crash in Newly Licensed Young Drivers. *The Journal of Pediatrics*, 2023. https://doi.org/In press.
10. Chapman, E. A., S. V. Masten, and K. K. Browning. Crash and Traffic Violation Rates before and after Licensure for Novice California Drivers Subject to Different Driver Licensing Requirements. *Journal of Safety Research*, Vol. 50, 2014, pp. 125–138. https://doi.org/10.1016/j.jsr.2014.05.005.
11. National Safety Council. Motor Vehicle - Age of Driver. Injury Facts, , 2025.
12. National Highway Traffic Safety Administration. Young Drivers. https://www.nhtsa.gov/book/countermeasures-that-work/young-drivers. Accessed Jul. 17, 2025.

13. Rolison, J. J., and S. Moutari. Combinations of Factors Contribute to Young Driver Crashes. *Journal of Safety Research*, Vol. 73, 2020, pp. 171–177. https://doi.org/10.1016/j.jsr.2020.02.017.
14. Wu, J. S., X. Dong, J. Green, and M. S. Ryerson. Role of the Built Environment, Roadway Characteristics, and Socioeconomic Factors in Keeping Teen Drivers Safe: An Investigation of the Factors Most Related to Teen Driver Fatalities. *Transportation Research Record*, 2024, p. 03611981241275543. https://doi.org/10.1177/03611981241275543.
15. Rahman, M. A., Md. M. Hossain, E. Mitran, and X. Sun. Understanding the Contributing Factors to Young Driver Crashes: A Comparison of Crash Profiles of Three Age Groups. *Transportation Engineering*, Vol. 5, 2021, p. 100076. https://doi.org/10.1016/j.treng.2021.100076.
16. Centers for Disease Control and Prevention. Risk Factors for Teen Drivers. *Teen Drivers*. https://www.cdc.gov/teen-drivers/risk-factors/index.html. Accessed Jul. 17, 2025.
17. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and National Center for Injury Prevention and Control. CDC WISQARS - Web-Based Injury Statistics Query and Reporting System. https://wisqars.cdc.gov/. Accessed Jul. 22, 2025.
18. IIHS-HLDI. Fatality Facts 2023: Teenagers. *IIHS-HLDI crash testing and highway safety*. https://www.iihs.org/research-areas/fatality-statistics/detail/teenagers. Accessed Jul. 22, 2025.
19. Federal Highway Administration. Average Annual Miles per Driver by Age Group. https://www.fhwa.dot.gov/ohim/onh00/bar8.htm. Accessed Jul. 22, 2025.
20. Keating, D. P. Understanding Adolescent Development: Implications for Driving Safety. *Journal of Safety Research*, Vol. 38, No. 2, 2007, pp. 147–157. https://doi.org/10.1016/j.jsr.2007.02.002.
21. Mayhew, D. R., H. M. Simpson, and A. Pak. Changes in Collision Rates among Novice Drivers during the First Months of Driving. *Accident Analysis & Prevention*, Vol. 35, No. 5, 2003, pp. 683–691. https://doi.org/10.1016/S0001-4575(02)00047-7.
22. McCartt, A. T., V. I. Shabanova, and W. A. Leaf. Driving Experience, Crashes and Traffic Citations of Teenage Beginning Drivers. *Accident Analysis & Prevention*, Vol. 35, No. 3, 2003, pp. 311–320. https://doi.org/10.1016/S0001-4575(02)00006-4.
23. Walshe, E. A., D. Romer, N. Aagaard, and F. K. Winston. Variation in Young Driver Training Requirements by State. *JAMA Network Open*, Vol. 7, No. 6, 2024, p. e2417551. https://doi.org/10.1001/jamanetworkopen.2024.17551.
24. Lund, A. K., A. F. Williams, and P. Zador. High School Driver Education: Further Evaluation of the Dekalb County Study. *Accident Analysis & Prevention*, Vol. 18, No. 4, 1986, pp. 349–357. https://doi.org/10.1016/0001-4575(86)90048-5.
25. Stock, J. R., J. K. Weaver, H. W. Ray, J. R. Brink, M. G. Sadof, and Battelle Memorial Institute. *Evaluation of Safe Performance Secondary School Driver Education Curriculum Demonstration Project*. Publication DOT-HS-806-568. 1983.
26. Curry, A. E., M. R. Pfeiffer, D. R. Durbin, and M. R. Elliott. Young Driver Crash Rates by Licensing Age, Driving Experience, and License Phase. *Accident Analysis & Prevention*, Vol. 80, 2015, pp. 243–250. https://doi.org/10.1016/j.aap.2015.04.019.
27. Shell, D. F., I. M. Newman, A. L. Córdova-Cazar, and J. M. Heese. Driver Education and Teen Crashes and Traffic Violations in the First Two Years of Driving in a Graduated

Licensing System. *Accident Analysis & Prevention*, Vol. 82, 2015, pp. 45–52. https://doi.org/10.1016/j.aap.2015.05.011.
28. Wu, S., X. Dong, E. A. Walshe, F. K. Winston, and M. S. Ryerson. Understanding Links Between Young New Drivers' Skills and Driver Training, Economic Conditions, and Home Neighborhood Urbanicity: Evidence from the State of Ohio (Accepted). *Transportation Research Record*.
29. Warnes, G. R., B. Bolker, T. Lumley, R. C. J. (Contributions from R. C. J. are C. (2005) SAIC-Frederick, I. F. by the I. R. Program, of the NIH, N. C. Institute, C. for C. R. under N. C. NO1-CO-12400), A. Muldoon, N. Jain, D. Enzmann, S. Højsgaards, U. Halekoh, M. Schwartz, and J. Rogers. Gmodels: Various R Programming Tools for Model Fitting. Mar 06, 2024.
30. Ohio Department of Public Safety. Ohio Crash Report Procedure Manual. , 2021.
31. Impact Teen Drivers. Understanding GRADUATED DRIVER LICENSING LAWS. .
32. Dong, X., J. S. Wu, E. A. Walshe, F. K. Winston, and M. S. Ryerson. Residing in a Driver Training Desert Leads to Delayed Licensure: Investigating the Relationship between Accessibility to Driver Training and Young Driver's Licensure. *Findings*, 2023. https://doi.org/10.32866/001c.85096.
33. Tefft, B. C., A. F. Williams, and J. G. Grabowski. Driver Licensing and Reasons for Delaying Licensure among Young Adults Ages 18-20, United States, 2012. *Injury Epidemiology*, Vol. 1, No. 1, 2014, p. 4. https://doi.org/10.1186/2197-1714-1-4.
34. Dong, X., J. S. Wu, S. T. Jensen, E. A. Walshe, F. K. Winston, and M. S. Ryerson. Financial Status and Travel Time to Driving Schools as Barriers to Obtaining a Young Driver License in a State with Comprehensive Young Driver Licensing Policy. *Accident Analysis & Prevention*, Vol. 191, 2023, p. 107198. https://doi.org/10.1016/j.aap.2023.107198.
35. Ryerson, M., J. Davidson, J. S. Wu, I. Feiglin, and F. Winston. Identifying Community-Level Disparities in Access to Driver Education and Training: Toward a Definition of Driver Training Deserts. *Traffic Injury Prevention*, Vol. 23, No. sup1, 2022, pp. S14–S19. https://doi.org/10.1080/15389588.2022.2125305.
36. Ohio Department of Public Safety. Find a Driving School. https://apps.dps.ohio.gov/DETS/public/schools. Accessed Jul. 28, 2025.
37. Pereira, R. H. M., M. Saraiva, D. Herszenhut, C. K. V. Braga, and M. W. Conway. R5r: Rapid Realistic Routing on Multimodal Transport Networks with R^5 in R. *Findings*, 2021. https://doi.org/10.32866/001c.21262.

Acknowledgements

The authors acknowledge Flaura Winston, Ph.D. (Division of General Pediatrics, Department of Pediatrics, University of Pennsylvania Perelman School of Medicine; Center for Injury Research and Prevention, Children's Hospital of Philadelphia (CHOP) Research Institute, Philadelphia, Pennsylvania) who provided input to this research question and analytical approach. The authors also acknowledge Shukai Cheng and Alex Gonzalez from the Department of Biomedical and Health Informatics at CHOP, and the Data Science and Biostatistics Unit at the CHOP Research Institute, provided support in geocoding the license address data. Last but certainly not least, the authors acknowledge the Ohio Department of Public Safety who partners with CHOP and

provided the data. This work was funded in part by the US National Highway Traffic Safety Administration through the Ohio Traffic Safety Office (NHTSA).

Conflict of Interest

The authors have no conflict of interest to declare.