Traffic Crashes, Violations, and Suspensions Among Young Drivers With ADHD

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abstract

OBJECTIVES: To compare monthly rates of specific types of crashes, violations, and license suspensions over the first years of licensure for drivers with and without attention-deficit/hyperactivity disorder (ADHD).

METHODS: We identified patients of New Jersey primary care locations of the Children's Hospital of Philadelphia who were born in 1987–1997, were New Jersey residents, had their last primary care visit at age ≥12 years, and acquired a driver's license (N = 14 936). Electronic health records were linked to New Jersey's licensing, crash, and violation databases. ADHD diagnosis was based on *International Classification of Diseases, Ninth Revision, Clinical Modification* diagnostic codes. We calculated monthly per-driver rates of crashes (at fault, alcohol related, nighttime, and with peers), violations, and suspensions. Adjusted rate ratios were estimated by using repeated-measures Poisson regression.

RESULTS: Crash rates were higher for drivers with ADHD regardless of licensing age and, in particular, during the first month of licensure (adjusted rate ratio: 1.62 [95% confidence interval: 1.18−2.23]). They also experienced higher rates of specific crash types: their 4-year rate of alcohol-related crashes was 2.1 times that of drivers without ADHD. Finally, drivers with ADHD had higher rates of moving violations (for speeding, seat belt nonuse, and electronic equipment use) and suspensions. In the first year of driving, the rate of alcohol and/or drug violations was 3.6 times higher for adolescents with ADHD.

CONCLUSIONS: Adolescents with ADHD are at particularly high crash risk in their initial months of licensure, and engagement in preventable risky driving behaviors may contribute to this elevated risk. Comprehensive preventive approaches that extend beyond current recommendations are critically needed.

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WHAT'S KNOWN ON THIS SUBJECT: In recent studies, it has been established that crash risk is higher among adolescents with attention-deficit/hyperactivity disorder. However, we know little about behavioral mechanisms underlying this risk, and no previous studies have examined risk during the newly licensed period.

WHAT THIS STUDY ADDS: This longitudinal study suggests that increased engagement in risky driving behaviors may be an important factor underlying elevated crash risk among adolescent drivers with attention-deficit/hyperactivity disorder. Findings highlight the critical need to develop comprehensive preventive approaches that extend beyond current recommendations.

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Attention-deficit/hyperactivity disorder (ADHD) is a common childhood disorder characterized by excessive levels of hyperactivity and impulsivity and/or inattention.[1] For the majority of children, ADHD persists into adolescence, when many become licensed to drive.[2,3] Skills that are critical in driving, including executive functioning, are frequently impaired in individuals with ADHD.[4,5] Indeed, licensing rates among adolescents with ADHD are lower than those among other adolescents.[6]

Early epidemiological studies suggested an increased crash risk among adolescent drivers with ADHD, but, as described in a previous article,[6] they had substantial methodologic limitations.[7–11] We recently conducted the first longitudinal examination of crash risk among adolescent drivers with community-identified ADHD; initial analyses revealed that the hazard rate of first-crash involvement was 36% higher among drivers with ADHD compared with that among other adolescents.[6] Authors of recent population-based studies of more serious crash-related outcomes (ie, hospital visits) reported similar findings.[12,13] However, there have been no studies to examine risk specifically during the newly licensed period (the period of highest lifetime crash risk and thus under the purview of graduated driver licensing [GDL] systems) or crash trajectories as adolescent drivers progress through licensure.

Additionally, research on the specific behavioral mechanisms underlying this elevated crash risk is lacking, limiting the ability to develop evidence-based prevention efforts for novice drivers with ADHD. Examining specific crash types (including single-vehicle crashes, crashes involving alcohol, at-fault crashes, and crashes occurring at night or with peers [2 high-risk driving conditions restricted for newly licensed adolescents under GDL[14]]), may provide critical insights on driving behaviors that are known to increase the likelihood of crashes or crash-related injuries and may be responsive to targeted intervention. In addition, authors of several previous studies have assessed traffic violations and license suspensions (both frequently used as proxies for risky driving) as well as self-reported risky behaviors (eg, drinking and driving) among these adolescents.[7,9–11] However, these studies revealed inconsistent findings and involved samples that were either small or more severely affected.[9,10] Moreover, drivers with ADHD have been found to overestimate their driving competence,[15] challenging the validity of self-reported measures and highlighting a critical need for studies in which objective traffic safety data are used.

To address these knowledge gaps, we conducted a large retrospective cohort study to compare monthly rates of overall and specific crash types, violations, and suspensions over the initial 4 years of licensure for adolescent drivers with and without ADHD; we hypothesized that rates would be higher among those with ADHD. To do this, we established a cohort of primary care patients at Children's Hospital of Philadelphia (CHOP) and leveraged a unique linkage of electronic health records (EHRs) and statewide traffic data.

METHODS

Study Cohort

Subjects were identified from the 6 New Jersey primary care practices within the CHOP network, which serves a socioeconomically, ethnically, and racially diverse population. Full details on the study's design are available elsewhere.[6] Briefly, we queried CHOP's EHR database to select individuals who (1) were born in 1987–1997; (2) were patients at a New Jersey CHOP primary care practice; and (3), to establish New Jersey residency, had a CHOP network visit as a New Jersey resident within 4 years of becoming age eligible to drive (at 16 years) and maintained a New Jersey address through their last CHOP visit. We identified a total of 19 588 individuals. We then excluded individuals with a diagnosed intellectual disability (n = 73); individuals with only 1 primary care visit (n = 676), to minimize ADHD misclassification; and individuals who had their last primary care visit before age 12 years (n = 317), to ensure that individuals were seen at an old enough age to confirm ADHD status.[1] The underlying cohort included 18 522 patients. We limited this study to adolescents who obtained an intermediate (initial) driver's license during the study period and had at least 1 month of post-licensure follow-up (n = 14 936; see Fig 1).

ADHD Classification

We classified subjects as having ADHD if their EHR indicated a 314.x *International Classification of Diseases, Ninth Revision, Clinical Modification* code either at a CHOP network visit or on the list of known conditions. A total of 1769 subjects were identified; 94% were classified on the basis of visits. We conducted a formal internal validation study of this classification scheme (sensitivity = 0.96; specificity = 0.98).[16]

Data Linkage

Details on the process and validation of data linkages are available in previous publications.[6,17] Briefly, we obtained records for individuals who received a New Jersey license through December 2014 from the New Jersey Motor Vehicle Commission; data included exact dates of licensure, license suspensions and restorations, and traffic violations issued. We also obtained data on all police-reported crashes in New Jersey from January 2004 to December 2014. We conducted a hierarchical deterministic linkage; 98% of New

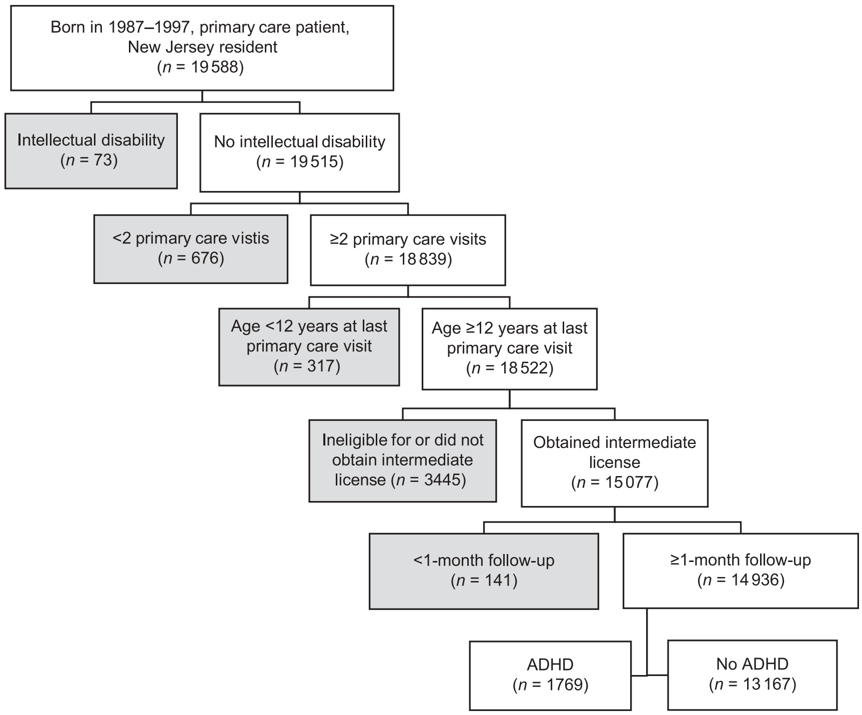

FIGURE 1
Flowchart revealing selection of study cohort. Gray boxes reveal individuals who were excluded from the study.

Jersey drivers involved in a crash linked to a licensing record. We then used similar methods to link this licensing-crash database with CHOP EHR data. We estimated the true-match rate (true matches divided by original matches) to be 99.95% and the false nonmatch rate (true matches not found) to be 1.5%.

Driving Outcomes

All subjects acquired an intermediate license in New Jersey, where the minimum licensure age is 17 years. In New Jersey, intermediate drivers licensed at age <21 years can drive independently (without adult supervision) but are restricted from driving between 11:01 PM and 4:59 AM, while using electronic equipment, or with >1 peer passenger for the first year. They are also prohibited from driving with any detectable amount of alcohol in their system.[18] Notably, New Jersey drivers age <21 years cannot plea bargain a point-carrying moving violation.

Primary crash outcomes for adolescent drivers were defined a priori and included (1) all crashes, reportable to police if an injury or >$500 in property damage occurred[19]; (2) injury crashes, in which at least 1 person had a moderate or greater severity injury (noted on crash report); (3) at-fault crashes, defined in previous work as those with a crash-contributing driver action (eg, inattention or unsafe speed)[20]; (4) night crashes, including crashes that occurred during New Jersey's restricted 11:01 PM to 4:59 AM period (late) and between 9:00 PM and 11:00 PM (early), a period also identified to be higher risk[21]; (5) passenger crashes, previously defined as crashes with only passengers aged 14 to 20 years (peer) or ≥2 passengers of any age (multiple)[22]; (6) single-vehicle crashes, the majority of which have been shown to involve speeding or traveling too fast for conditions[23]; and (7) alcohol-related crashes, in which the driver was issued a violation for alcohol use or noted on the crash report to have a blood alcohol content level of ≥0.01 for drivers age <21 years and ≥0.08 for drivers age ≥21 years. We calculated monthly rates per 10 000 driver-months; the numerator was the number of crashes among validly licensed drivers, and person-time was calculated by summing for all drivers the proportion of the month that the driver had a valid license. Average monthly rates for the first 12 and 48 months were estimated. Follow-up time concluded at 48 months after licensure, at death, or at end of the study period, whichever occurred first.

Using similar methods, we calculated the monthly rate of violations issued for (1) all traffic offenses; (2) point-carrying moving violations, which include (a) speeding, (b) careless driving, (c) alcohol and/or drug use, and (d) electronic equipment use; (3) seat belt nonuse; and, (4) for intermediate drivers age <21 years, violation of GDL restrictions (eg, nighttime or passenger restrictions). Finally, exact periods of license suspension were identified; suspension rates were calculated as the number of days in which a driver had a suspended license per year of follow-up since the date of licensure.

Other Variables

Demographic variables were ascertained from the EHR. Two co-occurring conditions that may affect crash risk were categorized via *International Classification of Diseases, Ninth Revision, Clinical Modification* codes: seizure disorder (345.x) and disruptive behavior disorder (DBD) (312.x or 313.81). DBD was further verified through EHR review by study authors (T.J.P. and B.E.Y.) and trained abstractors; confirmation included ≥3 visits for DBD, independent sources (eg, provider notes), or symptoms consistent with DBD. We used 2010 Census Gazetteer Files and

2007–2011 American Community Survey data to categorize residence zip code at last visit into quintiles of population density and median household income, respectively.[24,25]

Statistical Analysis

We compared bivariate distributions of demographic and clinical characteristics among drivers with and without ADHD using χ^2 and Wilcoxon rank-sum tests. Crash and violation risk within the first 12 and 48 months of licensure were compared by using χ^2 statistics; estimates were restricted to drivers followed to the specified post-licensure month. We estimated adjusted rate ratios (adjRRs) and 95% confidence intervals (CIs) using generalized estimating equation models with a log link (ie, Poisson distribution). For models, we accounted for correlation within individual drivers using an independent correlation structure. Potential covariates were chosen a priori on the basis of known or suspected association with ADHD (or its diagnosis) and outcomes, including sex, race and/or ethnicity, insurance payer, DBD and seizure disorders, licensing age (17 years 0 months, 17 years 1 month–17 years 11 months, 18 years, and ≥19 years), primary care practice, and birth year. Models also included indicators for zip code–level household income and population density as well as linear and quadratic terms for month since licensure to control for temporal trends. Analyses of GDL violations were restricted to drivers licensed at age <21 years and only through the first year of licensure. For rarer outcomes (alcohol-related crashes, violations for alcohol and/or drug use

TABLE 1 Demographic and Clinical Characteristics of Study Cohort; Comparing Drivers With and Without ADHD

	ADHD Status			
	Overall (*N* = 14 936)	ADHD (*n* = 1769)	No ADHD (*n* = 13 167)	*P* (ADHD Versus No ADHD)
Age at licensure, median (IQR), y	17.1 (17.0–17.6)	17.3 (17.0–18.0)	17.0 (17.0–17.6)	<.001
Follow-up time, median (IQR), mo	48 (31–48)	48 (28–48)	48 (32–48)	<.001
Age at last primary care visit, median (IQR), y	18.1 (16.5–19.1)	18.3 (17.1–19.6)	18.1 (16.4–19.1)	<.001
No. CHOP primary care visits, median (IQR)	21 (11–34)	27 (16–42)	20 (11–33)	<.001
Sex, *n* (%)				<.001
Female	7480 (50.1)	495 (28.0)	6985 (53.0)	
Male	7456 (49.9)	1274 (72.0)	6182 (47.0)	
Race and/or ethnicity, *n* (%)				<.001
Non-Hispanic white	9620 (64.4)	1317 (74.4)	8303 (63.1)	
Non-Hispanic black or African American	2176 (14.6)	205 (11.6)	1971 (15.0)	
Non-Hispanic other	2754 (18.4)	208 (11.8)	2546 (19.3)	
Hispanic	386 (2.6)	39 (2.2)	347 (2.6)	
Payer at last visit, *n* (%)				<.001
Private	13 802 (92.4)	1681 (95.0)	12 121 (92.1)	
Medicaid or self-pay	437 (2.9)	42 (2.4)	395 (3.0)	
Not recorded or not billed	697 (4.7)	46 (2.6)	651 (4.9)	
DBD, *n* (%)[a]				<.001
No	14 389 (96.3)	1506 (85.1)	12 883 (97.8)	
Yes	547 (3.7)	263 (14.9)	284 (2.2)	
Seizure disorder, *n* (%)				<.001
No	14 727 (98.6)	1710 (96.7)	13 017 (98.9)	
Yes	209 (1.4)	59 (3.3)	150 (1.1)	
Neighborhood income, *n* (%), $				<.001
≤57 226	2714 (18.2)	298 (16.8)	2416 (18.3)	
57 227–72 857	5530 (37.0)	598 (33.8)	4932 (37.5)	
72 858–87 222	3521 (23.6)	458 (25.9)	3063 (23.3)	
87 223–105 888	2451 (16.4)	305 (17.2)	2146 (16.3)	
≥105 889	696 (4.7)	110 (6.2)	586 (4.5)	
Unknown	24 (0.2)	0 (0)	24 (0.2)	
Neighborhood population density, *n* (%), population per square mile				.14
≤408	1811 (12.1)	236 (13.3)	1575 (12.0)	
409–1223	3950 (26.4)	472 (26.7)	3478 (26.4)	
1224–2615	5685 (38.1)	673 (38.0)	5012 (38.1)	
2616–4876	3204 (21.5)	349 (19.7)	2855 (21.7)	
≥4877	271 (1.8)	39 (2.2)	232 (1.8)	
Unknown	15 (0.1)	0 (0)	15 (0.1)	

IQR, interquartile range.

[a] DBD includes conduct disorder and oppositional defiant disorder.

[12 months after licensure], and licensure suspension), fully adjusted models failed to converge; thus, models were adjusted only for sex and licensing age. Analyses were conducted in SAS version 9.4 (SAS Institute, Inc, Cary, NC). This study was approved by the CHOP Institutional Review Board.

RESULTS

Twelve percent of the cohort had a diagnosis of ADHD (Table 1). The majority of subjects were long-term CHOP primary care patients and were last seen at a median age of 18.1 years. Drivers with ADHD were licensed a median of 3.6 months later than those without ADHD and were more likely to be male and non-Hispanic white.

A higher proportion of young drivers with ADHD crashed within the first month (2.8% vs 1.9%; *P* = .007; not shown), 12 months, and 4 years of licensure (Table 2). The adjusted crash rate in the first month after licensure was 62% higher than that among drivers without ADHD (294.0 vs 187.6 per 10 000 driver-months; adjRR: 1.62 [95% CI: 1.18−2.23]; Fig 2A). After adjusting for potential covariates and temporal trends, the 4-year crash rate of novice adolescent drivers with ADHD was 37% higher than that of drivers without ADHD (95% CI: 1.26−1.48; Fig 3, Supplemental Table 3). In addition, in analyses limited to drivers with ADHD, we found that crash rates of novice drivers who were licensed older versus younger did not differ; for example, there did not appear to be a difference in the 12-month rate for drivers licensed at age ≥18 years and those licensed at age 17 years (adjRR: 1.10 [95% CI: 0.83−1.44]).

Drivers with ADHD also experienced higher rates of crash subtypes (crashes involving passengers and at-fault, single-vehicle, injury, and alcohol-related crashes; Fig 3, Supplemental Table 3). For example, in the first 48 months after licensure, drivers with ADHD had a 62% higher rate of injury crashes (95% CI: 1.23−2.14) and a 109% higher rate of alcohol-related crashes (95% CI: 1.16−3.76). Notably, these 2 outcomes were rare events; within the 48-month study period, 4.3% of young drivers with ADHD were involved in an injury crash, and 1.2% were involved in an alcohol-related crash (Table 2).

Among drivers with ADHD, 35.6% were issued a traffic violation, and 26.8% were issued a moving violation within their first year of driving (compared with 25.3% and 18.6%, respectively, among drivers without ADHD; Table 2). Rates of moving violations were consistently higher for drivers with ADHD over the study period (at 48 months adjRR: 1.47 [95% CI 1.36−1.58]; Figs 2B and 4). Similarly, rates for specific violations, including careless driving and speeding, were higher among drivers with ADHD. Violation rates for other

TABLE 2 Risk of Crash Involvement, Traffic Violations, and License Suspension Within 12 and 48 Months After Licensure; Comparing Drivers With and Without ADHD

	Within 12 Months Post-Licensure			Within 48 Months Post-Licensure		
	ADHD (*n* = 1593)	No ADHD (*n* = 12 066)	*P*	ADHD (*n* = 985)	No ADHD (*n* = 8089)	*P*
	No. Drivers (%)	No. Drivers (%)		No. Drivers (%)	No. Drivers (%)	
Crashes						
All crashes	316 (19.8)	1951 (16.2)	<.001	461 (46.8)	2943 (36.4)	<.001
At fault	259 (16.3)	1456 (12.1)	<.001	370 (37.6)	2130 (26.3)	<.001
Peer passenger	113 (7.1)	664 (5.5)	.01	148 (15.0)	877 (10.8)	<.001
Single vehicle	57 (3.6)	312 (2.6)	.02	108 (11.0)	559 (6.9)	<.001
Multiple passenger	47 (3.0)	224 (1.9)	.003	60 (6.1)	355 (4.4)	.02
Early night	29 (1.8)	172 (1.4)	.22	41 (4.2)	298 (3.7)	.45
Injury	28 (1.8)	114 (0.9)	.003	42 (4.3)	219 (2.7)	.006
Late night	22 (1.4)	106 (0.9)	.05	55 (5.6)	261 (3.2)	<.001
Alcohol related	5 (0.3)	11 (0.1)	.01	12 (1.2)	47 (0.6)	.02
Violations						
All violations	567 (35.6)	3053 (25.3)	<.001	721 (73.2)	4703 (58.1)	<.001
Moving violations	427 (26.8)	2247 (18.6)	<.001	619 (62.8)	3898 (48.2)	<.001
Careless driving	225 (14.1)	1193 (9.9)	<.001	387 (39.3)	2094 (25.9)	<.001
Speeding	135 (8.5)	663 (5.5)	<.001	299 (30.4)	1750 (21.6)	<.001
Electronic equipment use	20 (1.3)	104 (0.9)	.12	76 (7.7)	385 (4.8)	<.001
Alcohol and/or drug use	17 (1.1)	31 (0.3)	<.001	35 (3.6)	175 (2.2)	.006
Seat belt nonuse	105 (6.6)	461 (3.8)	<.001	229 (23.2)	1334 (16.5)	<.001
GDL restrictions[a]	68 (4.4)	343 (2.9)	.001	—	—	—
License suspension	45 (2.8)	171 (1.4)	<.001	168 (17.1)	813 (10.1)	<.001

Risk is estimated among drivers who were followed to the specified post-licensure month. —, not applicable.

[a] Risk of GDL violations (eg, nighttime or passenger restrictions) was limited to drivers licensed before age 21 y (ADHD: *n* = 1563; no ADHD: *n* = 11 920) and estimated only for the first 12 mo after licensure.

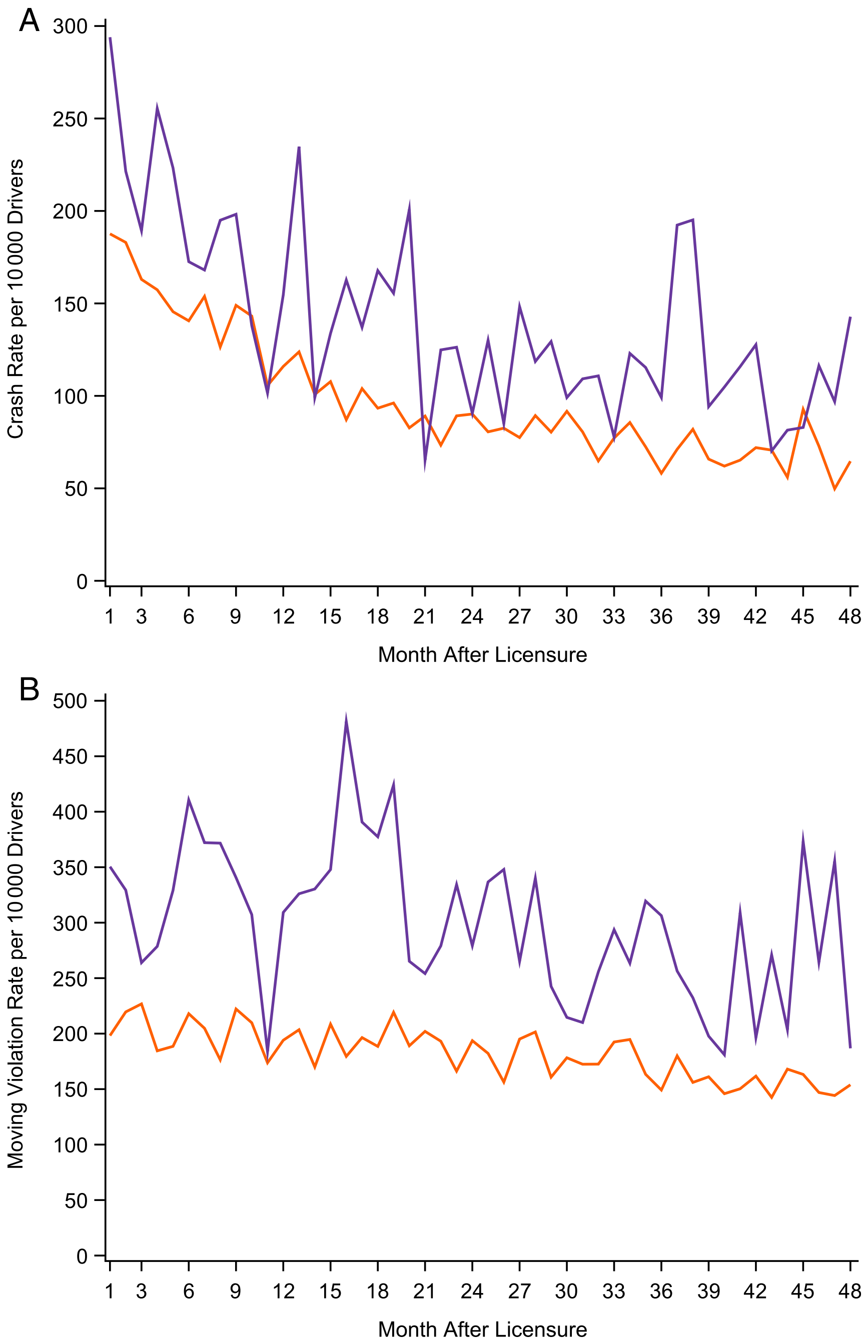

FIGURE 2

A, Monthly observed rate per 10 000 driver-months of crash involvement. B, Monthly observed rate per 10 000 driver-months of moving violations. Drivers with and without ADHD were compared over the first 4 years of licensure. Purple lines indicate drivers with ADHD and orange lines indicate drivers without ADHD.

risky driving behaviors were also elevated, including for alcohol and/or drug violations, which were an estimated 3.57 and 1.61 times higher over the first year and over 4 years of licensure, respectively. GDL violations did not appear to be elevated among those with ADHD (adjRR: 1.06 [95% CI: 0.80−1.40]). Finally, 17.1% of drivers with ADHD and 10.1% of drivers without ADHD had their license suspended at least once in the 4-year period, with average suspension rates of 13.5 and 7.0 days per driver-year, respectively (adjRR: 1.32 [95% CI: 1.08−1.61]; Table 2, Fig 4, Supplemental Table 3).

DISCUSSION

With this study, we provide the first longitudinal assessment of crash, violation, and suspension risk among adolescent drivers with ADHD. Findings indicate that adolescent drivers with ADHD have a moderately increased crash risk, a finding consistent with several recent population-based studies of adolescent and adult drivers with ADHD[12,13] but lower than estimates in early small studies of adolescents more severely affected.[11] In addition, with our study, we uniquely identify the early licensure period as a time of particularly high risk and the potential contribution of preventable factors to increased risk. These findings both offer important implications for families and for professionals working with them and highlight the need to develop comprehensive preventive approaches to reduce these adolescents' crash risk.

First, this study suggests that risky driving behaviors may underlie elevated crash risk of adolescent drivers with ADHD. Their risk of alcohol-related crashes (albeit low on an absolute scale) remained considerably higher over time, and the relative risk of several risky driving–related crash types was comparatively higher than that of all crash types. In addition, drivers with ADHD had a higher risk of violations for speeding, seat belt nonuse, alcohol and/or drug use, and electronic equipment use. This is consistent with literature revealing that individuals with ADHD are more likely to engage in risk-taking behaviors such as risky sexual activity and substance abuse.[26,27] Importantly, many risky driving behaviors may be amenable to change. Although medication may

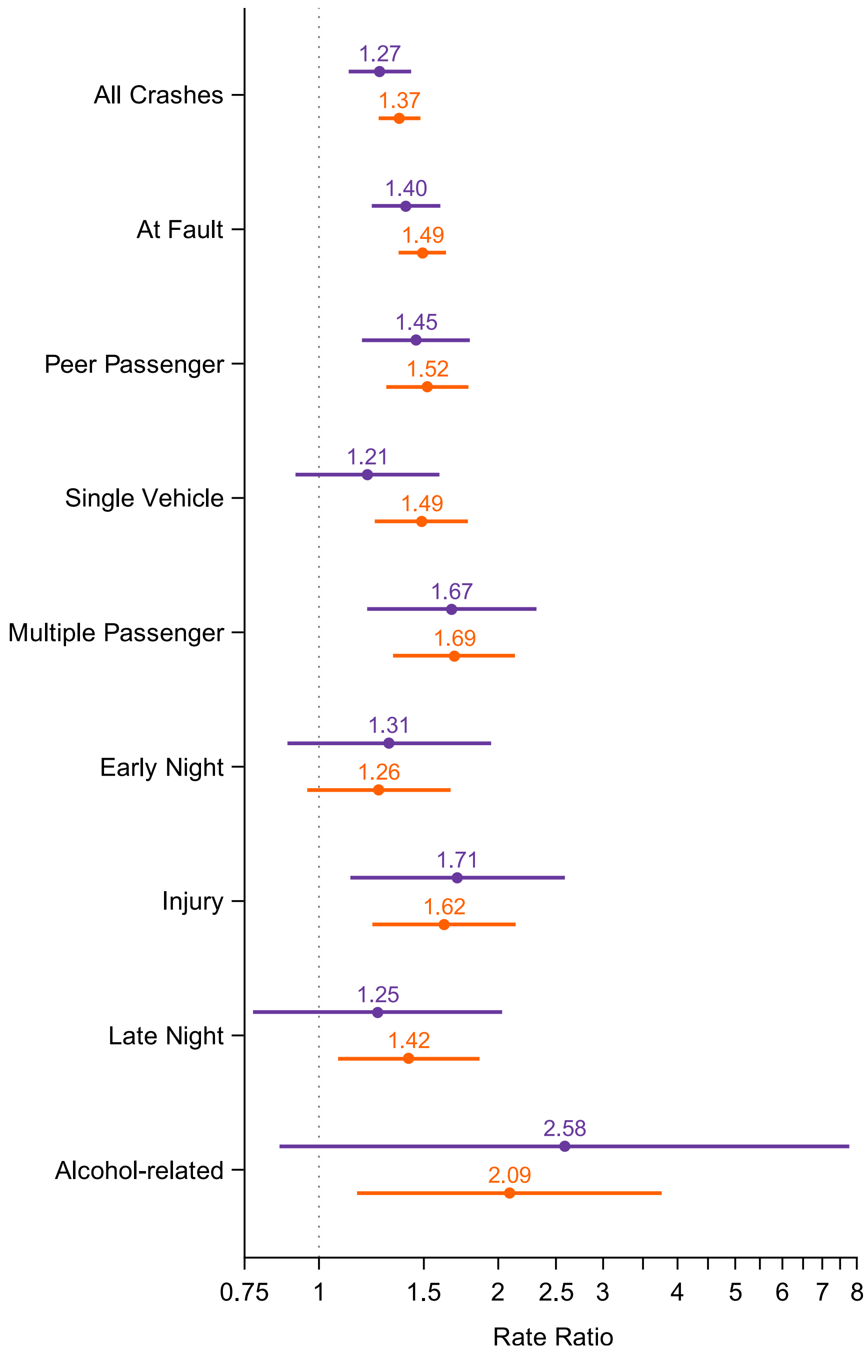

FIGURE 3

AdjRRs and 95% CIs for crash outcomes; comparing drivers with and without ADHD. Dots indicate the estimated adjRR, and lines indicate the width of the 95% CI from repeated-measures Poisson regression models. Purple dots and lines compare outcomes for 12 months after licensure. Orange dots and lines compare outcomes for 48 months after licensure.

improve driving performance for drivers with ADHD[28,29] (and thus is a primary recommendation to families[30]), there is not firm evidence that medication reduces adolescents' engagement in certain risky behaviors.[31] In addition, there are serious medication adherence issues in adolescence, and our previous study revealed that few adolescents with ADHD are medicated at the time of licensure and detected no differences in crash risk by medication status at licensure.[6,32] Thus, novel nonpharmacologic preventive approaches that capitalize on adolescents' desire for independence and that incorporate skill-training approaches for ADHD (which reveal evidence of effectiveness[33]) should be strongly considered to promote safe driving. Research suggests that risky behaviors among adolescents with ADHD may be mediated by suboptimal decision-making.[34,35] As such, approaches may include training teenagers in decision-making skills in the context of driving and parent training to promote independent, responsible driving behavior. In addition, shared decision-making involving the health care provider, parent, and adolescent (strongly affirmed by the Institute of Medicine) is recommended for the development of intervention plans that balance best provider practices with the goals and preferences of adolescents and their families.[36] Additional research is needed to shape shared decision-making practices for youth with ADHD as they learn to drive. Finally, vehicles are increasingly equipped with advanced safety features specifically designed to reduce young drivers' risk (eg, preset speed limits). Future studies to investigate the effect of these features on driving behaviors, and further, how adolescents interact with these features, are needed.

Second, in this study, we reported that crash risk is particularly heightened in the initial month of licensure and is elevated for novice drivers regardless of age at licensure. Our finding of a 62% increased rate for adolescent drivers with ADHD in their first month of driving reveals that they may be at their most vulnerable just after licensure. This is of particular concern because in general, teenagers are at their highest risk during the first 6 to 12 months

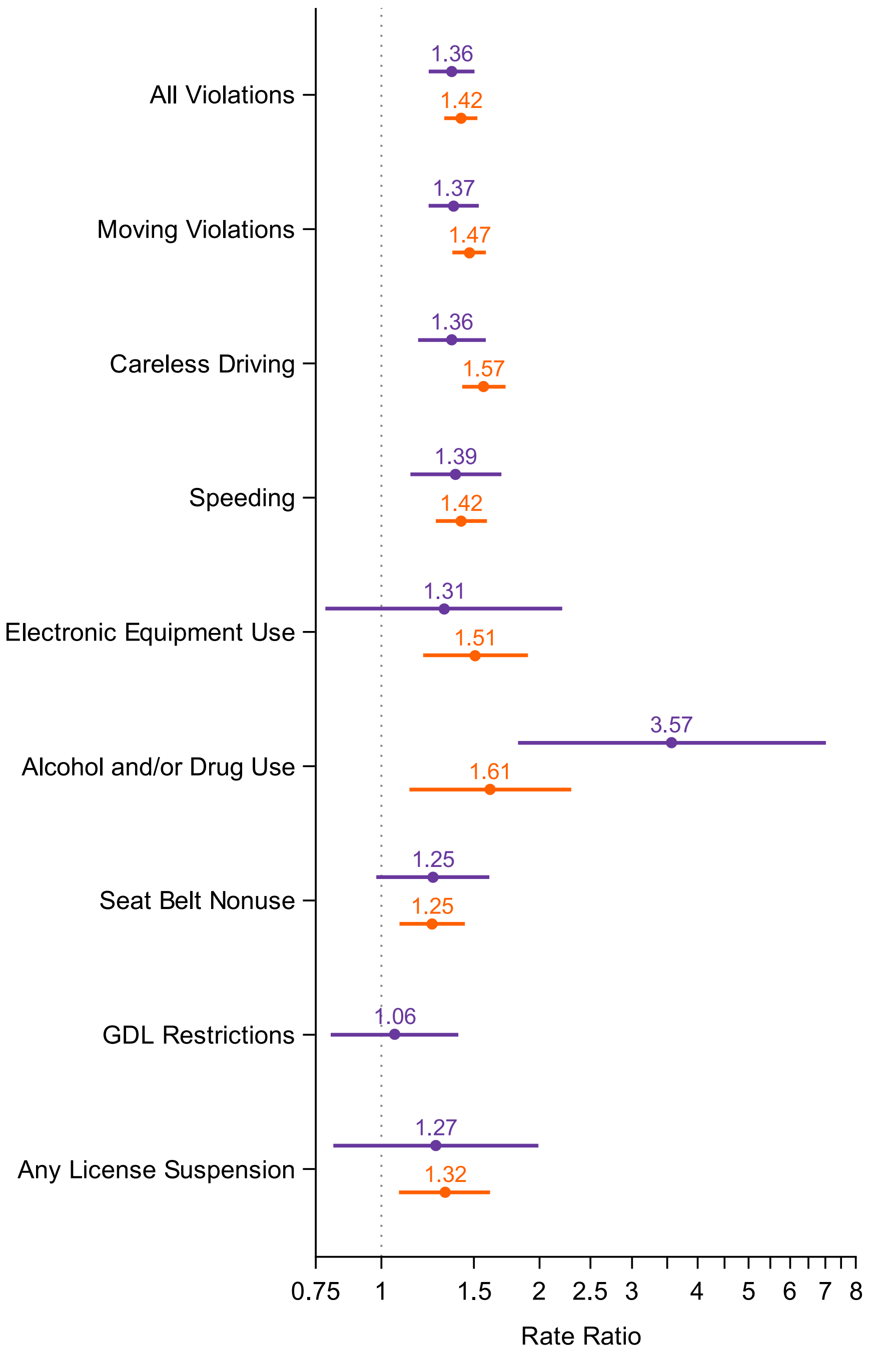

FIGURE 4
AdjRRs and 95% CIs for violation and license suspension outcomes; comparing drivers with and without ADHD. Dots indicate the estimated adjRR, and lines indicate the width of the 95% CI from repeated-measures Poisson regression models. Purple dots and lines compare outcomes for 12 months after licensure. Orange dots and lines compare outcomes for 48 months after licensure.

after licensure.[37,38] Although parents of adolescents with ADHD are frequently guided to delay licensure,[30] our results reveal that (contrary to the general population of adolescent drivers[38]) those with ADHD who delay licensure do not experience a lower crash risk once licensed. This finding may have important implications. In the vast majority of US states, adolescents who delay licensure until age ≥18 years are licensed outside the protective benefits of a GDL system (the most proven intervention to reduce young drivers' crash risk[39]). Thus, providers may encourage families inquiring about readiness to drive to seek the assistance of a certified driving rehabilitation specialist (educator specializing in training drivers with medical conditions) during the learner's permit phase and to adopt GDL-like household rules for teenagers who are not under GDL purview.

Strengths of this study include its longitudinal nature, use of objective measures of outcomes, ability to account for potential covariates (sex, licensing age, time since licensure, and co-occurring conditions), and increased generalizability to the general population of adolescents with ADHD by using a community-identified cohort. A primary limitation is that diagnoses relied on assessment by primary care providers; however, we previously validated ADHD diagnosis codes with high sensitivity and specificity.[16] Nevertheless, our sample may more appropriately be characterized as individuals with a lifetime history of ADHD because diagnoses occurred before adolescence and because some individuals may not have had ADHD-related impairments at the time of licensure.[40] Additionally, driving exposure was not directly measured. Several previous studies found that those with ADHD reported driving more miles[8,41]; however, these studies were limited in the authors' assessment of exposure (eg, usual driving at time of survey) and reliance on self-reports, which might have been subject to positive illusory bias.[15] In our analyses, we accounted for time since licensure, a proxy for exposure and itself critically important given that crash risk declines over the initial years of driving. In this study, we also used crash and violation events as proxies for engagement in risky driving behavior; future studies in which naturalistic driving methodologies are used would provide additional crucial insights.[42] Adolescents with ADHD may be less likely than adolescents without ADHD to leave the state for postsecondary education[43,44]; this may lead to an overestimation of true rate ratios. However, rates were elevated in the 12-month period after licensure, before most subjects completed high school. In addition, generalizability may be limited as a result of New Jersey's licensing age (the oldest in the United States) and high urbanization. Finally, the 12% prevalence of ADHD in our study cohort was higher than estimates of 8% to 9% ever diagnosed for New Jersey children[45]; this may be influenced by CHOP's reputation and corresponding care-seeking behavior of parents.

CONCLUSIONS

Adolescent drivers with ADHD are at particularly high crash risk in their initial months of licensure, and engagement in preventable risky driving behaviors likely underlies this increased risk. Prospective studies to objectively measure risky driving behaviors among novice drivers with ADHD and examine the extent to which these behaviors mediate driving outcomes are vital to inform prevention strategies. The development of comprehensive preventive approaches to reduce crash risk is critically needed.

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ABBREVIATIONS

ADHD: attention-deficit/hyperactivity disorder
adjRR: adjusted rate ratio
CHOP: Children's Hospital of Philadelphia
CI: confidence interval
DBD: disruptive behavior disorder
EHR: electronic health record
GDL: graduated driver licensing

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