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Comparison of Motor Vehicle Crashes, Traffic Violations, and License Suspensions Between Autistic and Non-Autistic Adolescent and Young Adult Drivers

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Objective: One-third of autistic individuals obtain a driver's license by age 21 years; however, prior studies suggest they may be at heightened risk for motor vehicle crashes. We compared objective rates of crashes, traffic violations, and license suspensions for newly licensed autistic and non-autistic adolescents.

Method: This retrospective cohort study included New Jersey residents born from 1987 through 2000 who were patients of the Children's Hospital of Philadelphia health care network. Electronic health records were linked with statewide driver licensing and crash databases. Autism status was classified via *International Classification of Diseases* (ICD) diagnostic codes; individuals with intellectual disability were excluded. We compared rates among 486 autistic and 70,990 non-autistic licensed drivers over their first 48 months of driving. Furthermore, we examined the proportion of crashes attributed to specific driver actions and crash types.

Results: Compared with non-autistic drivers, autistic drivers were estimated to have lower average monthly rates of crash involvement (adjusted rate ratio (adjRR) = 0.89, 95% CI = 0.75–1.05), moving violations (adjRR = 0.56, 95% CI = 0.48–0.67), and suspensions (adjRR = 0.32, 95% CI = 0.18–0.58). Among drivers involved in a crash, autistic drivers were half as likely to crash because of unsafe speed, but substantially more likely to crash because of their failure to yield to a vehicle/pedestrian and while making left-turns or U-turns.

Conclusion: Newly licensed autistic adolescent drivers have similar to lower estimated rates of adverse driving outcomes; the extent to which these can be attributed to different driving patterns is a critical point for future investigation. There were several notable differences in the characteristics of these crashes, which directly inform interventions to improve driving safety of autistic adolescent drivers.

Key words: automobile driving, adolescent health, autistic disorder, developmental disabilities, traffic accidents

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The transition from adolescence to adulthood can be challenging for autistic adolescents and their families, as many services that they received as children are no longer available.[1,2] A national survey reported that more than 1 in 3 young autistic adults did not transition to employment or education after high school, 1 in 4 are socially isolated, and 1 in 3 had no community participation in the past year.[3] These missed opportunities can have substantial long-term consequences on independence and quality of life.[4,5] For autistic adolescents without intellectual disability (hereafter referred to as autistic adolescents), becoming licensed to drive may dramatically increase their mobility by allowing them to independently travel to places of employment, school, and social activities.[6] Furthermore, driving is associated with improved autonomy, quality of life, and psychological well-being,[7,8] which may ultimately improve autistic adolescents' long-term physical and mental health.[9] Recent studies have found that the majority of parents of autistic adolescents are interested in having their child drive independently.[10] Despite high interest, only approximately 1 in 3 autistic adolescents obtain a license to drive independently by age 21 years.[11]

There is preliminary evidence to suggest that autistic adolescents may be at heightened risk for motor vehicle crashes and other poor driving outcomes. Autism without intellectual disability is characterized by subtle impairments in social cognition, visual–motor integration, motor coordination, visual processing speed, and executive functioning, skills known to be critical to safe driving.[12,13] In addition, comorbid attention-deficit/hyperactivity disorder (ADHD) and anxiety disorders are common among autistic adolescents and may contribute to driving challenges.[14] Small driving simulator studies found some differences in driving behavior between autistic and non-autistic drivers[14]; in 1 study, young autistic drivers were more likely to divert their gaze away from the roadway,[15] and a second study reported increased variability in speed and/or lane management in certain driving environments (eg, rural roads).[16] Licensed autistic adults also rated their ability to drive lower than non-autistic adults.[17] Furthermore, in a survey of parents and caregivers of autistic adolescents, the majority reported that autism "moderately" to "extremely" negatively influenced their child's driving ability.[18]

Given both the importance of safely empowering the independence and mobility of autistic adolescents and the potential for heightened risk for adverse driving outcomes, research on driving outcomes among autistic adolescents and young adults is essential. However, little is known about whether real-world driving outcomes differ for autistic and non-autistic adolescents. To date, no study has comprehensively and objectively examined the real-world risk of crashes and traffic violations—a proxy for risky driving—among autistic adolescents. Furthermore, we know little about whether and how crash circumstances differ for autistic drivers. This limits our ability to develop evidence-based medical, behavioral, technological, and educational interventions tailored to this population.

Thus, we conducted the first longitudinal study to examine on-road driving outcomes among newly licensed autistic adolescent drivers. Specifically, we identified via electronic health records (EHR) a cohort of more than 90,000 children who resided in the state of New Jersey (NJ) and were patients of the Children's Hospital of Philadelphia (CHOP) pediatric health care network and linked their medical records to records from NJ's statewide traffic databases. We aimed to compare for autistic and non-autistic adolescent drivers the rate of (1) overall police-reported crashes as well as at-fault crashes, injury crashes, nighttime crashes, and crashes with peer passengers; (2) traffic violations, which include moving violations (eg, speeding, failure to yield) and violations of New Jersey's Graduated Driver Licensing (GDL) policy; and (3) license suspensions. In addition, among autistic and non-autistic adolescent drivers who crashed during their first 4 years of licensure, we examined the prevalence of crash-contributing driver actions (eg, inattention, unsafe speed), crash responsibility (ie, fault), and crash types (eg, rear-end crash). We hypothesized that the social, cognitive, and motor challenges associated with autism would place these individuals at a heightened risk for adverse driving outcomes.

METHOD

Study Design

Individuals for this retrospective cohort study were identified from the CHOP pediatric health care network, which serves socioeconomically and racially diverse patients at more than 50 inpatient and outpatient locations throughout southeastern Pennsylvania and southern New Jersey. CHOP providers manage all aspects of clinical care using a unified and linked electronic health record (EHR) system. We queried the CHOP EHR historical database to identify all patients who were born 1987 through 2000, had an office visit as a New Jersey resident within 4 years prior to becoming eligible for their learner's permit at 16 years of age (ie, 12−15 years of age), and maintained New Jersey residency through their last CHOP network visit (n = 90,409) (Figure 1). We then excluded 854 individuals who had intellectual disability (ID), as these adolescents were unlikely to obtain licenses. ID was defined as the presence of an *International Classification of Diseases Ninth Revision Clinical Modification* (ICD-9-CM) code beginning with 317, 318, or 319 or an *ICD-10-CM* code beginning with F70, F71, F72, F73, F78, or F79 either from a CHOP visit or on the individual's list of known medical conditions (ie, "problem list"). After applying these exclusions, we identified a cohort of 89,555 patients.

Patients were classified as having a diagnosis of autism if they had an *ICD-9-CM* code beginning with 299, 299.0, or 299.8 or an *ICD-10-CM* code of F84.0, F84.5, F84.8, or F84.9 either at a CHOP office visit or on their problem list. As described in a previous paper, we assessed the validity of this algorithm by manually reviewing the EHR of patients classified as having autism[11]; we were able to find an independent source in the EHR (eg, letter, provider notes) confirming an autism diagnosis for 77% of patients. In total, 1,489 patients (1.7%) were classified as having a diagnosis of autism (Figure 1).

Linkage of EHR and Driving Data

We linked CHOP EHR data to traffic safety data during construction of the New Jersey Safety and Health Outcomes (NJ-SHO) data warehouse, a unique source of linked data for 22 million New Jersey residents. Briefly, we conducted a large probabilistic linkage using LinkSolv software (Strategic Matching, Inc.) to link EHR data to 2 administrative sources: (1) the New Jersey Motor Vehicle Commission's Licensing Database (2004−2017), which contains detailed licensing information for each New Jersey licensee as well as the date and type of all traffic violations and license suspensions; and (2) the New Jersey Department of Transportation's Crash Record Database (2004−2017), which contains detailed data from the New Jersey crash report for all police-reported crashes that occurred in the state. Common identifiable data elements used in the linkage included full name, exact date of birth, sex, ZIP code, and residential address. The linkage was formally validated and found to be of high quality. Details about the NJ-SHO warehouse development and linkage process and evaluation are described elsewhere.[19] Using these linked data, we constructed each individual's full history of driver licensing, police-reported crashes, traffic violations, and license suspensions over the study period of January 1, 2004, through December 31, 2017.

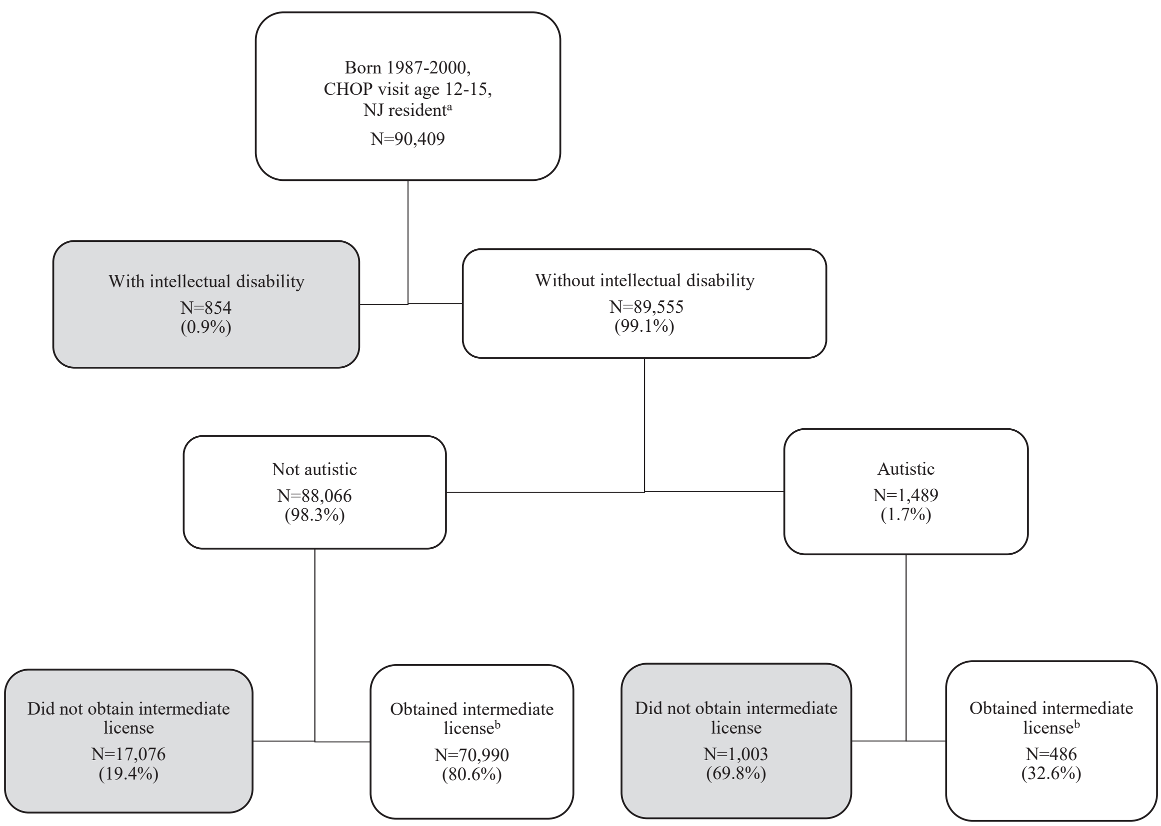
Analytic Population

The current study was limited to drivers who obtained a NJ driver's license during the study period and were licensed for at least 1 month by the study's end. Under New Jersey's GDL policy, residents are eligible to obtain an intermediate license at a minimum age of 17 years after having had a learner's permit for at least 6 months. Intermediate drivers are permitted to drive without adult supervision, but are prohibited for 12 months from driving at nighttime and are limited to 1 passenger unless a parent or guardian is in the vehicle. The final study cohort consisted of 71,476 drivers who obtained an intermediate driver's license, including 486 autistic drivers and 70,990 non-autistic drivers (Figure 1). Each driver was followed over time, beginning on the date of intermediate licensure and concluding at the final license expiration, death, or end of the study period, whichever occurred first.

Driving Outcomes

Primary driving outcomes included overall police-reported crashes, traffic violations, and license suspensions among autistic and nonautistic licensed drivers. Crashes in New Jersey are reportable if an injury or more than $500 in property damage occurred.[20] We also considered 4 secondary crash outcomes. At-fault crashes were identified using methods established in our previous studies[21]: we determined the adolescent driver to be at fault if they were noted on the crash report to have made at least 1 crash-contributing driver action. Investigating officers are

FIGURE 1 Flowchart Depicting Selection of Final Study Cohort



Note: Gray boxes show individuals who were excluded from the study.
[a]New Jersey (NJ) resident is defined as a patient who maintained NJ residence from their last visit to the Children's Hospital of Philadelphia (CHOP) between ages 12 and 15 years through their last CHOP visit.
[b]Includes drivers licensed for at least 1 month before end of study period.

instructed to determine the most prominent proximate factors (up to 2 per driver) that contributed to the crash.[22] Specific driver actions are listed on the New Jersey crash report, including unsafe speed, failure to yield the right of way, following too closely, improper lane change, backing unsafely, and driver inattention, as well as a designation for "other driver action." Injury crashes included crashes in which 1 or more of the individuals involved had a moderate or greater severity injury (as noted on crash report). Nighttime crashes were those that occurred from 9:01 pm through 4:59 am, a period designated as higher risk for novice adolescent drivers.[23] Finally, peer passenger crashes included when the driver was carrying only passengers 14 to 20 years of age, a condition that increases crash fatality risk for young drivers.[23] Moving violations included citations that resulted in points being issued to the license; these include speeding, following too closely, and careless driving. We also identified GDL violations over the first year of licensure for drivers licensed younger than 21 years of age.

In addition, we investigated the specific circumstances of crashes that occurred during the study period. The proportion of all crashes in which the adolescent driver performed specific crash-contributing driver actions were noted. For crashes in which the driver was determined to be at fault, we further assessed crash configuration—that is, the manner in which the vehicle crashed with another vehicle or other object. Configurations include crashes in which the driver's vehicle crashes with another vehicle as follows: (1) in the same direction (rear-end) as the striking (or index) vehicle; (2) in the same direction (rear-end) as the struck vehicle; (3) in the same direction (side-swipe); (4) at a right angle; (5) while executing a left-turn or U-turn; (6) while backing up; or (7) striking a parked vehicle. Crash configurations also included crashes that occurred with something other than a motor vehicle (eg, a fixed object or an animal).

Other Variables

Age at licensure was derived from the driver's dates of birth and licensure. We ascertained sex from the licensing database and the following from the EHR: race/ethnicity, insurance payor at last CHOP visit, diagnosis of ADHD (*ICD-9-CM* code beginning with 314 or an *ICD-10-CM* of F90 at CHOP visit or problem list), and diagnosis of anxiety disorder (*ICD-9-CM* code beginning with 300 or *ICD-10-CM* beginning with F40, F41, F42, F44, F45, or F48). We also geocoded the residential address of each driver (using crash report as a primary source and licensing data as a secondary source) to their residential census tract (ArcGIS 10.5.1, Esri, Readlands, CA). We obtained the median household income and population estimates for each New Jersey census tract from the 2013 through 2017 American Community Survey 5-year estimates and geographic area (square miles) from the 2010 Census Gazetteer Files.[24,25] We calculated population density (population per square mile) and categorized census tracts into quintiles of median household income and population density.

Statistical Analyses

We compared bivariate distributions of demographic and clinical characteristics among autistic and non-autistic drivers using χ^2 test for categorical variables and Wilcoxon rank-sum tests for continuous variables. Driving outcomes were analyzed in 2 complementary ways. First, we used survival analysis methods to compare the time to first crash and first moving violation among autistic and non-autistic drivers. Kaplan−Meier survival curves were used to estimate cumulative probability (risk) of first crash involvement over time; log-rank tests were used to compare differences. We used multivariable Cox regression models to estimate adjusted hazard ratios (adjHR) and 95% CIs of driving outcomes. Adjusted models included potential covariates chosen *a priori* based on known or suspected association with autism diagnosis and driving outcomes, including age at licensure (17 years 0 months, 17 years 1 month to 17 years 11 months, 18 years, 19 years and older), birth year, sex, race/ethnicity, insurance payor, diagnosis of ADHD, diagnosis of anxiety disorder, and indicators for quintile of census tract-level median household income and population density. To assess the proportionality assumption—that is, whether the association between autism status and crash risk remained constant over time—we used Kolmogorov-type supremum tests and tested the interaction of autism status and follow-up time.

In the second complementary analysis, we calculated monthly crash and traffic violation rates of autistic and non-autistic drivers over the first 12 and 48 months of licensure. For each month, the numerator was the number of days with a police-reported crash or violation event that occurred among licensed drivers; the person-time denominator was calculated by summing for all drivers the proportion of the month that the driver had a valid license. Annual rates of license suspension were also calculated as the number of days with a suspended license per year. Adjusted rates were compared via estimation of rate ratios and 95% CI using generalized estimating equations (GEE) repeated-measures analysis with a log-link function to specify Poisson regression. Models accounted for correlation among crashes, violations, or suspensions within individual drivers using an independent covariance structure to control for within-driver temporal correlation and included aforementioned covariates plus linear and quadratic terms for month since

TABLE 1 Demographic Characteristics of the Study Cohort

Characteristic	All drivers (N = 71,476)	Autistic drivers (n = 486)	Non-autistic drivers (n = 70,990)	*p*
Age at last primary care visit, y, median (IQR)	17.9 (16.3, 18.8)	17.8 (16.7, 19.1)	17.9 (16.2, 18.8)	.71
Age at licensure, y, median (IQR)	17.0 (17.0, 17.5)	17.6 (17.1, 18.4)	17.0 (17.0, 17.5)	<.001
Age at the end of the study period, y, median (IQR)	22.7 (20.0, 25.9)	21.5 (19.4, 24.7)	22.7 (20.0, 25.9)	<.001
Sex, n (%)				<.001
Female	35,533 (49.7)	70 (14.4)	35,463 (50.0)	
Male	35,943 (50.3)	416 (85.6)	35,527 (50.0)	
Race/ethnicity, n (%)				<.001
Non-Hispanic White	52,444 (73.4)	407 (83.7)	52,037 (73.3)	
Non-Hispanic Black	6,574 (9.2)	27 (5.6)	6,547 (9.2)	
Hispanic	2,848 (4.0)	8 (1.6)	2,840 (4.0)	
Non-Hispanic other/unknown	9,610 (13.4)	44 (9.1)	9,566 (13.5)	
Insurance payor, n (%)				<.001
Private	64,398 (90.1)	459 (94.4)	63,939 (90.1)	
Medicaid or self-pay	1,930 (2.7)	14 (2.9)	1,916 (2.7)	
Not recorded or not billed	5,148 (7.2)	13 (2.7)	5,135 (7.2)	
ADHD, n (%)				<.001
No	65,526 (91.7)	229 (47.1)	65,297 (92.0)	
Yes	5,950 (8.3)	257 (52.9)	5,693 (8.0)	
Anxiety disorder, n (%)				<.001
No	67,620 (94.6)	336 (69.1)	67,284 (94.8)	
Yes	3,856 (5.4)	150 (30.9)	3,706 (5.2)	
Quintiles of median household income of residential census tract, $, n (%)				.32
First: <48,506	4,747 (6.6)	21 (4.3)	4,726 (6.7)	
Second: 48,506–66,937	12,312 (17.2)	82 (16.9)	12,230 (17.2)	
Third: 66,938–84,921	18,512 (25.9)	131 (27.0)	18,381 (25.9)	
Fourth: 84,922–110,035	20,223 (28.3)	138 (28.4)	20,085 (28.3)	
Fifth: ≥110,036	15,315 (21.4)	111 (22.8)	15,204 (21.4)	
Unknown	367 (0.5)	3 (0.6)	364 (0.5)	
Quintiles of population density of residential census tract, population per square mile, n (%)				.02
First: <1,299	25,425 (35.6)	193 (39.7)	25,232 (35.5)	
Second: 1,299–2,919	23,173 (32.4)	168 (34.6)	23,005 (32.4)	
Third: 2,920–5,237	16,002 (22.4)	90 (18.5)	15,912 (22.4)	
Fourth and fifth: ≥5,238	6,509 (9.1)	32 (6.6)	6,477 (9.1)	
Unknown	367 (0.5)	3 (0.6)	364 (0.5)	

***Note**: ADHD = attention-deficit/hyperactivity disorder; IQR = interquartile range.*

licensure to control for temporal trends. Finally, in models of overall crashes and violations, we tested for statistical interaction of autism with time since licensure, licensing age, sex, ADHD, and anxiety disorder using type 3 score statistics; all interaction terms were nonsignificant and thus not included in final models.

Finally, using data on all crashes experienced by each driver within 12 and 48 months of licensure, we compared the prevalence of crash-contributing driver actions and proportion of at-fault crashes by crash configuration for autistic and non-autistic drivers. We used GEE log-binomial regression models to estimate adjusted prevalence ratios (adjPR) and accounted for multiple crashes per driver using an independent covariance structure. In accordance with strong guidance from the fields of epidemiology and statistics, we do not conduct null hypothesis significance testing using an arbitrary α level; instead, we present interval estimation to convey the precision of point estimates for adjusted models.[26] Analyses were conducted using SAS version 9.4 (SAS Institute Inc, Cary, NC). This study was approved by the Children's Hospital of Philadelphia's Institutional Review Board.

RESULTS

Description of Study Cohort

Autistic drivers were licensed at a median age of 17.6 years of age (interquartile range [IQR] = 17.1, 18.4), somewhat later that non-autistic drivers (median [IQR] = 17.0 [17.0, 17.5]; $p < .001$). The median age at the end of follow-up was greater than 21 years for both groups (Table 1). A comparison of other relevant characteristics is shown in Table 1. Autistic drivers were more likely to be male, to be non-Hispanic White, to have private insurance, and to be diagnosed with ADHD and anxiety.

Crash Involvement

Overall, 163 of 486 (33.5%) autistic drivers and 27,018 of 70,990 (38.1%) non-autistic drivers were involved in a police-reported crash by the end of the study period (Figure 1). The Kaplan−Meier survival curve in Figure 2a shows the proportion of autistic and non-autistic licensed drivers who were involved as a driver in a crash over time. An estimated 15% (95% CI = 12%–19%) of autistic drivers and 17% (16%–17%) of non-autistic drivers experienced their first police-reported crash within the first 12 months of licensure; the estimated proportion who crashed within 48 months were also similar for the 2 groups (autistic drivers: 37% [32%–43%]; non-autistic drivers: 36% [36%–36%]). After adjusting for covariates in Cox regression models, the overall rate to first crash over the follow-up period was estimated to be slightly lower for autistic drivers (adjHR = 0.89; 95% CI = 0.76–1.04). Among those who crashed, the median time to first crash was 16 months among autistic drivers and 17 months for non-autistic drivers ($p = .27$).

We also compared the average monthly crash rate (per 10,000 licensed drivers) over the first 12 and 48 months of licensure for autistic and non-autistic drivers. After adjusting for covariates, the average monthly overall crash rate over the first 12 months of licensure was estimated to be slightly lower for autistic drivers than non-autistic drivers (152.2 and 152.6 per 10,000 drivers, respectively; adjusted rate ratio [adjRR] = 0.87, 95% CI = 0.69–1.10) (Figure 3; see also Table S1, available online). Absolute crash rates declined for both autistic and non-autistic groups over the first 48 months (48-month average monthly crash rate: 116.1 and 106.6, respectively), whereas the adjusted relative rate remained similar (0.89 [0.75–1.05]). As shown in Figure 3, point estimates and corresponding 95% CI suggest that autistic drivers have similar or lower rates of at-fault crashes, injury crashes, nighttime crashes, or peer passenger crashes.

Crash Circumstances

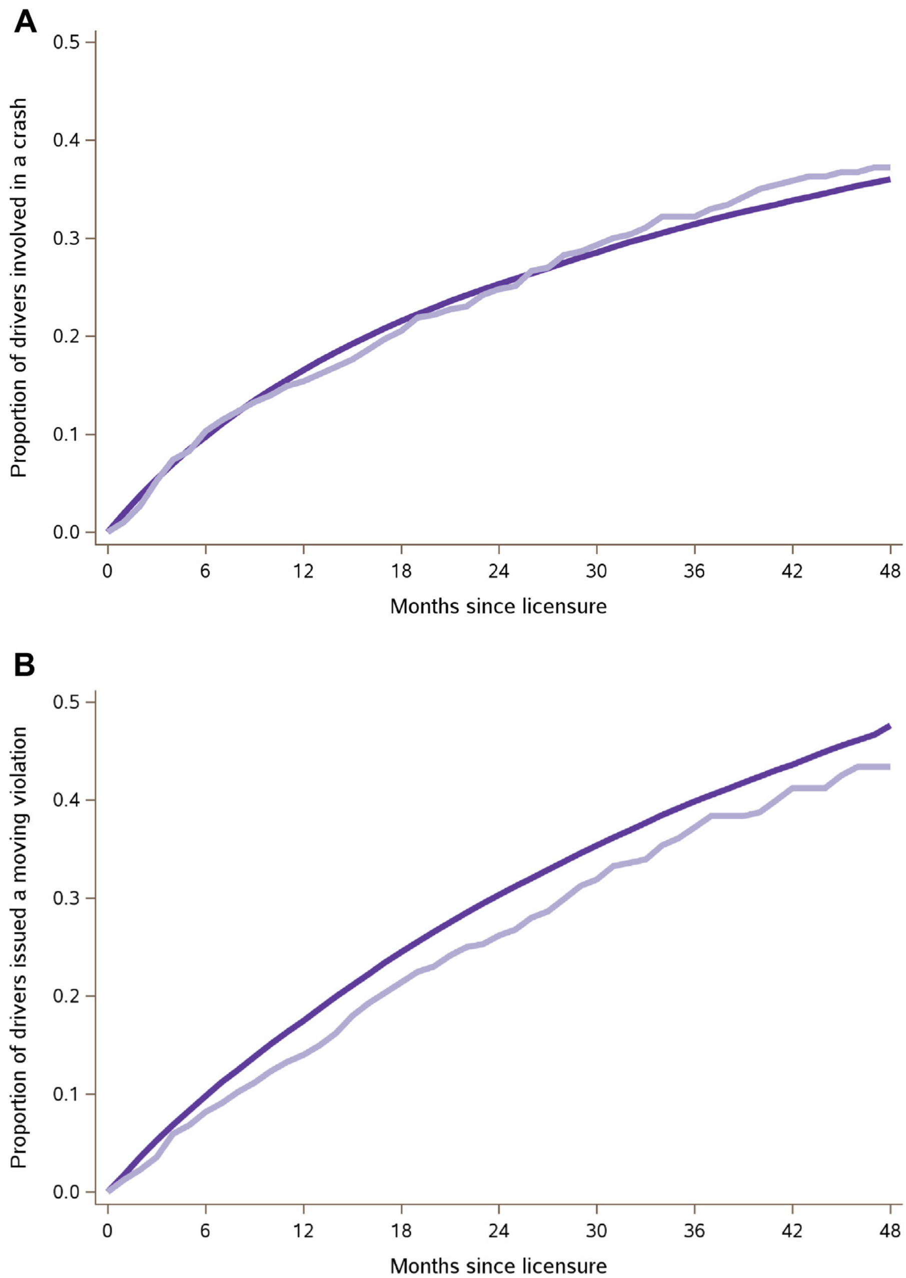
There were a total of 187 crash-involved autistic drivers and 28,842 crash-involved non-autistic drivers during the first 48 months of licensure. (Note that an individual driver could have been involved in 1 or more crashes over the study period, so this analysis includes 139 autistic drivers and 21,926 non-autistic drivers who crashed at least once in the 48-month period.) Table 2 compares the proportion of crash-involved drivers who were at fault for their crash and committed selected crash-contributing driver actions. The majority of autistic and non-autistic crash-involved drivers were at fault for their crash (72.7% and 67.1%, respectively); the likelihood of the driver being at fault was not higher for autistic drivers (adjPR = 1.00 [0.91–1.10]). The most common crash-contributing driver action among both autistic and non-autistic drivers was driver inattention, which accounted for 46.0% and 39.3% of all crashes (1.06 [0.91–1.24] (Table 2). Notably, autistic drivers were an estimated 77% more likely than non-autistic drivers to have their crash due to a failure to yield right of way to a vehicle or pedestrian (1.77 [1.25–2.50]). Conversely, they were an estimated 44% less likely to have their crash due to unsafe speed (0.56 [0.32–0.99]).

Table 2 also shows the most common crash configurations of crashes involving autistic and non-autistic drivers during the first 48 months of licensure and who were determined to be at fault for their crash. The most common type of crash of both autistic and non-autistic drivers was a rear-end crash as the striking vehicle (33.1% and 37.2%, respectively; adjPR = 0.86 [0.69–1.09]). We did not observe large differences in the frequency of various crash configurations between the 2 groups, with 1 notable exception: crashes involving at-fault autistic drivers were more than 3 times as likely as crashes of non-autistic drivers to occur while making a left-turn or U-turn (11.8% versus 4.4%; 3.30 [2.09–5.22]).

Traffic Violations and License Suspensions

The proportion of autistic and non-autistic licensed drivers issued a moving violation over 48 months post-licensure is

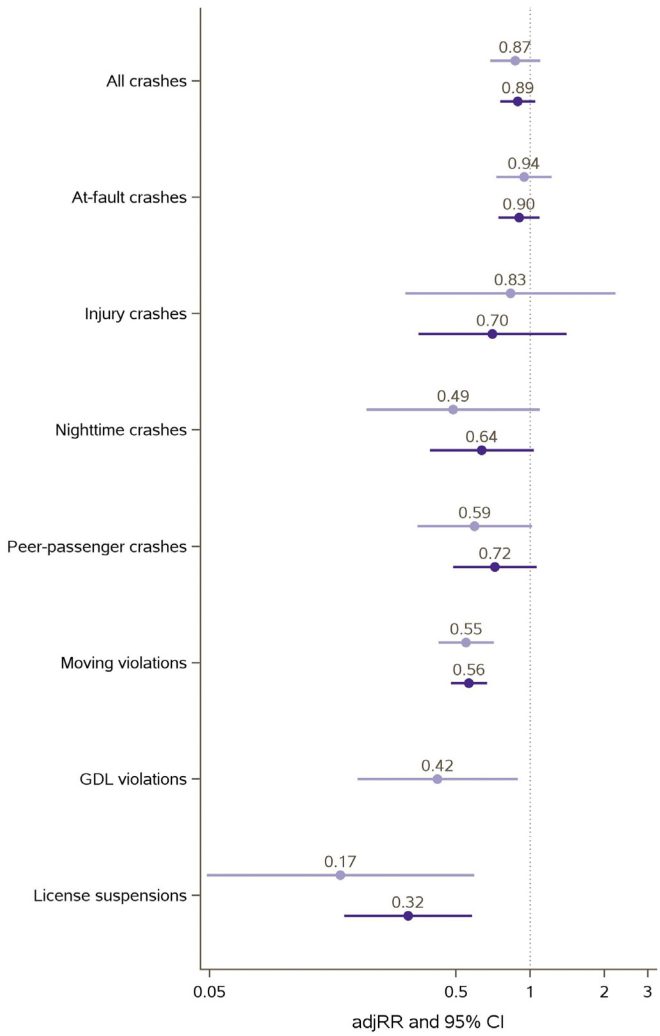
FIGURE 2 Inverse Kaplan−Meier Curves Depicting the Proportion of Drivers (A) Involved in a Crash and (B) Issued a Moving Violation, by Months Since Licensure and Autism Status



Note: *Light purple line indicates autistic drivers, and dark purple line indicates non-autistic drivers. Log-rank test compared differences among unadjusted survival curves for autistic versus non-autistic drivers for crashes (χ^2 = 0.174,* p *= .68) and for moving violations (χ^2 = 1.337,* p *= .25). Please note color figures are available online.*

illustrated in a Kaplan−Meier survival curve in Figure 2b. The risk of being issued at least 1 moving violation was markedly lower for autistic drivers compared with non-autistic drivers over the first 12 months post-licensure (14%; 95% CI = [11%–18%] versus 17% [17%–18%]) and 48 months (43% [38%–49%] versus 48% [47%–48%]). In adjusted analyses for the 12-month post-licensed period, autistic drivers had an estimated 45% lower rate of moving violations (0.55 [0.42–0.71]; note $adjRR_{autistic\ vs.\ non\text{-}autistic}$ is equivalent to $adjRR_{non\text{-}autistic\ vs.\ autistic}$ = 1 / 0.56 = 1.79 [1.49–2.08]), 58% lower rate of GDL violations (0.42 [0.20–0.89]; $adjRR_{non\text{-}autistic\ vs.\ autistic}$ = 2.38 [1.13–5.02]), and an 83% lower rate of license suspensions (0.17 [0.05–0.59], $adjRR_{non\text{-}autistic\ vs.\ autistic}$ = 5.89 [1.69–20.53]) (Figure 3; see also Table S1, available online).

FIGURE 3 Adjusted Rate Ratio (adjRR) and 95% CIs for Crash and Violation Outcomes Comparing Autistic and Non-autistic Drivers



Note: *Dots indicate the estimated adjRR, and lines indicate the width of the 95% CI from repeated-measures Poisson regression models. Light purple dots and lines compare outcomes for 12 months after licensure. Dark purple dots and lines compare outcomes for 48 months after licensure. Note that results are presented on the logarithmic scale. GDL = graduated driver licensing. Please note color figures are available online.*

DISCUSSION

This is the first longitudinal study to compare objective on-road driving outcomes among newly licensed autistic and non-autistic adolescent drivers. Our analyses of administrative driving records indicate that autistic adolescent and young adult drivers have similar to lower crash rates compared with non-autistic drivers. Furthermore, rates of other adverse driving outcomes frequently used as indicators of risky driving are substantially higher among non-autistic drivers: compared with autistic drivers, they have 1.8 times the rate of moving violations, 2.4 times the rate of GDL violations, and almost 6 times the rate of license suspensions. With respect to crash circumstances, there were some important differences in the ways that autistic and non-autistic drivers crashed. Specifically, autistic drivers were less likely to crash because of unsafe speeds but more likely to crash because of failure to yield the right of way and while making left-turns or U-turns.

A majority of parents of autistic adolescents indicated interest in having their adolescent drive.[10] However, autistic drivers rated their overall driving ability lower than non-autistic drivers,[17] and driving instructors who provide behind-the-wheel training to autistic adolescents noted that autistic individuals require far more instructional time and individualized support to acquire safe driving skills.[27,28] Despite potential driving challenges and contrary to our hypothesis, our study revealed that autistic adolescents have a lower driver-level likelihood of police-reported crash involvement. The implications of this finding warrants further discussion. Notably, per-driver crash rates estimate the probability of crash involvement among drivers with a valid license; thus, they do not account for differences in driving patterns or differential exposure to various road conditions. There is good indication that, compared with their non-autistic counterparts, autistic drivers' driving is more limited.[17,27-29] For example, adult autistic drivers reported driving an average of 1 fewer day per week and were more likely to place voluntary restrictions on their driving.[17] Qualitative interviews with specialized driver instructors also support the notion that autistic young drivers may limit their driving to more familiar or low-risk routes.[28] Consequently, per-driver crash rates may not reflect differences in the inherent riskiness of driving (eg, differences in risk on a per-mile basis) between the 2 groups. However, our findings remain noteworthy in that they suggest that licensed autistic drivers may establish driving patterns that balance independent mobility and risk—thus bringing their probability of crash involvement in line with other young drivers. Interestingly, simulator studies comparing standard measures of vehicle control (variability in speed/lane position) between autistic and non-autistic drivers showed relatively fewer differences among licensed drivers than unlicensed drivers, and in a previous study we found the vast majority of autistic adolescents who obtain a learner's permit go on to licensure.[11] These and the current study's findings collectively suggest autistic individuals may need more intensive support and intervention to develop the range of skills needed to acquire licensure—in particular, in more challenging traffic scenarios[30]—but that, once they do, they may be safe independent drivers. Prospective studies are critically needed to provide further insights on how autistic drivers navigate the road compared with non-autistic drivers

TABLE 2 Prevalence and Adjusted Prevalence Ratios (adjPR) for Driver Actions Among All Crash-Involved Drivers and Crash Configurations Among At-Fault Crash-Involved Drivers, 48 Months Post-Licensure, Autistic Versus Non-autistic Drivers

Driver actions among all crashes	Autistic drivers (n = 187)	Non-autistic drivers (n = 28,842)	adjPR[a] (95% CI)
At-fault crashes	136 (72.7)	19,367 (67.1)	1.00 (0.91, 1.10)
Driver inattention	86 (46.0)	11,345 (39.3)	1.06 (0.91, 1.24)
Failure to yield the right of way to vehicle/pedestrian	30 (16.0)	2,507 (8.7)	1.77 (1.25, 2.50)
Following too closely	21 (11.2)	2,710 (9.4)	1.04 (0.69, 1.57)
Unsafe speed	11 (5.9)	2,525 (8.8)	0.56 (0.32, 0.99)
Improper lane change	6 (3.2)	769 (2.7)	0.94 (0.42, 2.08)
Backing unsafely	5 (2.7)	1,054 (3.7)	0.74 (0.31, 1.77)
Crash configurations among at-fault crashes	**Autistic drivers (n = 136)**	**Non-autistic drivers (n = 19,367)**	**adjPR[a] (95% CI)**
Rear-end crash (index vehicle)	45 (33.1)	7,199 (37.2)	0.86 (0.69, 1.09)
Right-angle crash	24 (17.6)	3,241 (16.7)	1.18 (0.81, 1.70)
Crash with another object (ie, non−motor vehicle)	20 (14.7)	3,140 (16.2)	0.78 (0.52, 1.18)
Left-turn/U-turn crash	16 (11.8)	846 (4.4)	3.30 (2.09, 5.22)
Side-swipe crash	14 (10.3)	1,732 (8.9)	1.07 (0.65, 1.77)
Struck parked vehicle	8 (5.9)	1,120 (5.8)	1.14 (0.53, 2.41)
Backing crash	3 (2.2)	1,040 (5.4)	0.49 (0.16, 1.52)
Rear-end crash (struck vehicle)	2 (1.5)	246 (1.3)	1.46 (0.36, 5.96)

Note: An individual driver can be involved in 1 or more crashes over the study period. adjPR = adjusted prevalence ratio.
[a]*Estimates were obtained using generalized estimating equation log-binomial regression model, accounting for within-driver correlation and controlling for sex, age at licensure, race/ethnicity, insurance payor, diagnosis of attention-deficit/hyperactivity disorder, diagnosis of an anxiety disorder, census tract-level indicators for median household income and population density, and birth year.*

and enable us to statistically account for these differences when estimating relative crash risk.

This study also provides evidence that traffic violations and license suspensions are much lower among autistic adolescents. Indeed, emerging research suggests that autistic individuals are more risk-averse than their non-autistic counterparts.[31,32] In addition, studies have highlighted that autistic drivers tend to be exceedingly adherent to the rules of the road.[28,33] Although this may lead to more inflexibility in adapting to an unexpected critical event, it may also make them less susceptible to intentional moving violations. Our findings contrast with those of a convenience self-report survey conducted by Daly *et al.*,[17] in which a higher proportion of surveyed autistic adult drivers (31%) reported a history of "traffic violations" in the past 2 years than non-autistic drivers (13%). This difference may be explained by limitations in self-report surveys—in particular, that autistic and non-autistic individuals may have different reporting tendencies—and that the construct of Daly *et al.* included traffic citations not indicative of driving safety (eg, parking tickets). Future studies should also continue to identify unique strengths and challenges in the driving behavior of autistic drivers so that tailored resources and interventions can be developed for this population.

This study is the first to examine how crash circumstances for autistic drivers may differ from those of non-autistic drivers. We found that although autistic young drivers were not more likely to be at fault for their crash than other drivers, they were much less likely to crash due to unsafe speed. This is notable, as traveling at an unsafe speed is the critical reason for one-third of all novice adolescent driver crashes.[34] The lower crash rate due to driving at unsafe speeds is consistent with rule-following behavior that has been reported by driver instructors as a strength of autistic drivers.[28] Conversely, autistic drivers were substantially more likely to have their at-fault crash occur due to a failure to yield right of way or while making a left-turn or U-turn. Driving simulator research has suggested that deficits in visual processing speed among autistic drivers may lead to difficulty in identifying, processing, and/or prioritizing potential hazards that include social factors (eg, pedestrians, cyclists).[35,36] Furthermore, our latter finding supports those of an Australian study that compared driving performance among 16 autistic and 21 non-autistic drivers using a standardized on-road driving assessment.[33]

Autistic drivers' steering at right-hand intersections (equivalent to US left-hand intersections) was observed to be more hesitant and slower, resulting in increased unsteadiness and incoordination. Such turns are complex maneuvers that require automation in basic maneuvering skills such as steering, as well as motor speed and visual scanning skills, both of which were slower among participating autistic drivers. In particular, Chee *et al.* hypothesized that poor automation in maneuvering may reduce autistic adolescents' cognitive bandwidth to "cope with the critical demand of information processing in driving" (p 2,668).[33] Collectively, these findings suggest that on-road training of autistic drivers should include special focus on navigating turns and interacting safely with pedestrians and other vehicles. Clinicians should strongly consider referring autistic adolescents who are interested in driving to occupational therapists who are certified driving rehabilitation specialists; these specialists can provide an in-depth assessment of an individual driver's potential fitness to drive and can provide training tailored to that driver's unique strengths and challenges.

As discussed above, a primary study limitation is our inability to account for driver exposure in crash risk estimates. However, our analyses inherently account for time since licensure, which has been used as a proxy for exposure and itself is a critically important variable given rapid declines in crash rates over the first few years of driving. In addition, autism diagnoses relied on assessment by health care providers rather than rigorous testing using gold-standard *DSM* criteria; however, we were able to confirm autism diagnosis using an independent source in EHRs for the large majority of patients. In addition, some crash outcomes in Table 2 were very rare, limiting our ability to detect true differences in rates. Finally, New Jersey has the oldest licensing age in the United States (at 17 years) and is highly urbanized, so there may be limits to generalizability to drivers of younger ages or in more rural jurisdictions.

Despite literature noting substantial driving challenges among autistic drivers, this study indicates that the per-driver risk of crash involvement for newly licensed autistic drivers is similar to that of their non-autistic counterparts. The extent to which this is attributable to different driving patterns or active effort on the part of autistic young drivers and their parents to balance independence and driving risk is a critical point for future investigation. We also identified several characteristics of real-world crashes that differ between autistic and non-autistic drivers, providing important insights regarding specific training that may need to be tailored to support the safety of autistic young drivers.

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