Impact of alcohol driving-while-impaired license suspension duration on future alcohol-related license events and motor vehicle crash involvement in North Carolina, 2007 to 2016

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ABSTRACT

Background/Purpose: License suspensions are a strategy to address alcohol-impaired driving behavior and recidivism following an alcohol driving while impaired (alcohol-DWI) conviction. Little is known about the specific impacts of conviction-related suspensions on safety outcomes and given recent fluctuations in alcohol-impaired driving behavior, crashes, and suspension trends, updated and focused assessments of this intervention are necessary. This study aimed to 1) examine the association between type of recent alcohol-DWI suspension and having a secondary alcohol-related license outcome and/or future crash event in North Carolina (NC) between 2007 and 2016; and 2) assess potential modification of these associations by race/ethnicity.
Methods: We used linked NC licensing data, NC crash data, and county-level contextual data from a variety of data sources. We compared individuals ages 21 to 64 who sustained initial (1-year) versus repeat (4-year) suspensions for alcohol-related license and crash involvement outcomes. We estimated unadjusted and adjusted hazard ratios (aHRs) using Cox proportional hazards models and produced Kaplan-Meier (KM) survival curves using a three-year follow-up period. After observing statistically significant modification by race/ethnicity, we calculated stratified aHRs for each outcome (Black and White subgroups only, as other subgroups had low numbers of outcomes).
Results: 122,002 individuals sustained at least one alcohol-DWI conviction suspension (117,244 initial, 4,758 repeat). Adjusted KM survival curves indicated that within three years of the index suspension, the predicted risks of having a license outcome and crash outcome were about 8 % and 15 %, respectively, among individuals with an initial suspension and 5 % and 10 %, respectively, among individuals with a repeat suspension. After adjusting for potential confounding, we found that compared to those with an initial suspension, those with repeat suspensions had a lower incidence of future license (aHR: 0.49; 95 % CI: 0.42, 0.57) and crash outcomes (aHR: 0.67; 95 % CI: 0.60, 0.75). Among Black individuals, license outcome incidence was 162 % lower among repeat versus initial index suspension groups (aHR: 0.38; 95 % CI: 0.26, 0.55), while for White individuals, the incidence was 87 % lower (aHR: 0.54; 95 % CI: 0.45, 0.64). Similarly, crash incidence for repeat versus initial suspensions among Black individuals was 56 % lower (aHR: 0.64; 95 % CI: 0.50, 0.83), while only 39 % lower among White individuals (aHR: 0.72; 95 % CI: 0.63, 0.81).
Conclusions: Decreased incidence of both license and crash outcomes were observed among repeat versus initial index suspensions. The magnitude of these differences varied by race/ethnicity, with larger decreases in incidence among Black compared to White individuals. Future research should examine the underlying mechanisms leading to alcohol-impaired driving behavior, convictions, recidivism, and crashes from a holistic social-ecological perspective so that interventions are designed to both improve road safety and maximize other critical public health outcomes, such as access to essential needs and services (e.g., healthcare and employment).

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1. Introduction

Alcohol-impaired driving is a critical public health problem in the US, with an estimated 18.5 million individuals driving under the influence of alcohol, resulting in 127 million episodes of alcohol-impaired driving in 2020 alone (Substance Abuse and Mental Health Services Administration (SAMHSA), 2022; Centers for Disease Control and Prevention, 2023). Motor vehicle crashes (MVCs) involving alcohol-impaired drivers accounted for 30 % of all traffic-related deaths in the US in 2020, or 11,654 deaths, a notable increase from the number of MVCs in 2019 (n = 10,196 deaths) [3]. In addition to fatal injuries, MVCs involving alcohol-impaired driving can result in severe injury, significant economic burden, and long-lasting impacts on quality of life (National Highway Traffic Safety Administration, 2022; Centers for Disease Control and Prevention, 2020; Blincoe et al., 2022).

Prior driving-while-impaired (DWI) behavior is considered a predictor of future DWI behavior (Ahlin et al., 2011); and among those who are arrested for driving while impaired by alcohol (alcohol-DWI), an estimated 25 % are repeat offenders with a prior history of related arrests (National Highway Traffic Safety Administration, 2005; National Highway Traffic Safety Administration, 2008; Warren-Kigenyi and Coleman, 2014; Impinen et al., 2009). Further, compared to drivers with no history of alcohol-DWI convictions, the risk of MVC resulting in fatal injury is increased among drivers with this prior history (Fell, 2014). Estimates of repeat alcohol-DWI events vary by the specific outcome examined and by state, with state estimates of arrests ranging from 11 to 41 %, convictions ranging from 11 to 69 %, and suspensions ranging from 11 to 79 % (Warren-Kigenyi and Coleman, 2014:9.). Although most studies indicate that recidivism in alcohol-impaired driving is highly prevalent, states use different follow-up periods and implement different suspension periods, and look-back periods further vary by analyses, making it difficult to compare alcohol-DWI outcomes. Further, studies that compared results using different look-back periods observed that longer look-back periods (e.g., 10 years or more) can substantially alter findings, with notable increases in recidivism estimates for arrests, convictions, and license suspensions (Warren-Kigenyi and Coleman, 2014:9.). Thus, there is a need for state-specific assessments of alcohol-impaired driving outcomes using longer look-back periods to conclusively determine the magnitude of the problem.

The overall deterrent effect of license suspension on alcohol-impaired driving is historically well-documented, and this consequence has been implemented as part of state DWI legislation across the US (Ferguson, 2012; Wagenaar et al., 2000; Peck, 1991; Klein, 1989; Peck et al., 1985; McCartt et al., 2003; DeYoung, 2011; Fell, 2019; Wagenaar and Maldonado-Molina, 2007; Nichols and Ross, 1990; DeYoung, 1997; Elder et al., 2011; Hagen, 1977; Hagen et al., 1979; Sadler et al., 1991). Several studies have cited suspension policies as an effective strategy for reducing rates of alcohol-DWI and alcohol-related crashes, compared to use of jail terms, fines, and alcohol education programs only (Peck et al., 1985; Nichols and Ross, 1990; DeYoung, 1997; Elder et al., 2011; Hagen, 1977; Hagen et al., 1979; Sadler et al., 1991). Existing suspension policies include pre-conviction (administrative) and conviction-related driver's license suspensions. A number of studies have explored potential deterrent effects of pre-conviction policies on safety-related outcomes, and have consistently observed significant reductions in alcohol-DWI recidivism and crashes after policy implementation (Klein, 1989; Voas et al., 2000; Voas et al., 2000). Although numerous studies have examined conviction-related license suspensions, they have done so in conjunction with other interventions, or as a comparison group for assessing effectiveness of newer interventions (e.g., ignition interlocks, treatment programs) (Peck et al., 1985; DeYoung, 2011; Wagenaar and Maldonado-Molina, 2007; Nichols and Ross, 1990; Hagen, 1977; Venkatraman et al., 2021; Mann et al., 2000; Bouffard et al., 2017; Brar, 2012; DeYoung and Gebers, 2004; Miller et al., 2015; Tashima and Marelich, 1989; Willis et al., 2004; Taxman and Piquero, 1998). However, there is a dearth of research on the effects of conviction-related suspensions by duration of suspension. Moreover, given changes in alcohol-impaired driving behavior, crashes, and alcohol-DWI suspension trends suggesting stagnation in declines, and even some increases, in recent years (National Highway Traffic Safety Administration, 2022; Singichetti et al., XXXX; Insurance Institute for Highway Safety, Highway Loss Data Institute, 2022), current assessments of suspension impacts are urgently needed.

Equity is also important to consider when examining alcohol-involved driving, traffic policing, crashes, and the impact of suspension policies. Several studies observed that White individuals had consistently greater risks of alcohol-involved driving behavior, compared to Black, Hispanic, and Other groups (Caetano and McGrath, 2005; Oh et al., 2020; Romano et al., 2010). In addition, studies of traffic stops and policing have identified racial disparities as systemic issues (Baumgartner et al., 2017; Roh and Robinson, 2009; Crozier and Garrett, 2019; Pierson et al., 2020; Baumgartner et al., 2018; Mughan and Carroll, 2021), including one analysis that observed that Black drivers were more likely to be stopped and searched in a traffic stop compared to White drivers, despite spending less time driving and being less likely to carry contraband (Baumgartner et al., 2018). Further, people of color are significantly overrepresented in alcohol-involved crashes and alcohol-involved driving arrest (Caetano and McGrath, 2005; Romano et al., 2010). Although license suspensions have the possible benefits of deterring harmful transportation-related outcomes to individuals and the larger society, they also have documented inequity by race and ethnicity (Singichetti et al., XXXX; Crozier et al., 2022; Lechner and Wicclair, 2021) while also placing a notable burden on livelihood (Crozier and Garrett, 2019; Bell v. Burson, 1971; Wells-Parker and Cosby, 1988). One study of alcohol-DWI convictions and alcohol-impaired driving behaviors observed that Latino/Hispanic men were more likely to be convicted of an alcohol-DWI compared to White men, relative to the frequency at which these groups engaged in alcohol-impaired driving behaviors (Kagawa et al., 2021). These findings collectively demonstrate a strong need for research that examines disparities in suspension and recidivism. Such research may help identify potential differences in behaviors and/or enforcement patterns, providing an increased understanding of areas for further exploration in order to ensure intervention strategies are equitable and reduce recidivism across all drivers.

Therefore, the purpose of this study was both to 1) examine the association between duration of recent license suspension and having a future alcohol-related license event and/or a future crash in North Carolina (NC) between 2007 and 2016 and 2) examine potentially different impacts on outcomes for racial and ethnic subgroups. Specifically, this research was undertaken in NC, where similar to the US overall, 30 % of all traffic fatalities are from MVCs involving an alcohol-impaired driver (National Highway Traffic Safety Administration, 2022). Additionally, while this study examined two critical safety-related outcomes (i.e., crashes and future license suspensions), research on recidivism and license suspension should be examined within a broader set of potential alcohol-DWI license suspension considerations. These include potential impacts on livelihood and access to essential services (e.g., employment, healthcare, substance use disorder treatment) (Crozier and Garrett, 2019; Syed et al., 2013; Wolfe et al., 2020; Lichtenwalter et al., 2006; Fletcher et al., 2010; Browne et al., 2016), which are of particular importance given the location of this study (i.e., in NC) where, like many states, there are several known barriers to mobility for individuals who cannot access a personal vehicle (Crozier and Garrett, 2019; NC First Commission, 2019). Therefore, we expand on this larger framework of considerations in the discussion, including additional research and information that is needed to form a comprehensive examination of suspension impacts.

2. Methods

2.1. Data sources

We used 2007–2016 NC licensing data, NC crash data, and county-level contextual data from a variety of data sources. We first identified individuals who had sustained alcohol-DWI license suspensions between 2007 and 2016 using NC licensing data from the NC Department of Motor Vehicles, an administrative dataset which contains records of all individuals who have a license-related event in NC. Next, we linked NC crash records to licensing data at the individual level. NC crash data include all reportable MVCs occurring in the state, defined as either a) resulting in a fatal or non-fatal personal injury; b) resulting in total property damage of at least $1,000; c) resulting in any degree of property damage to a vehicle seized; or d) involving a vehicle that was seized per NC policy (Division of Motor Vehicles, 2023). Crash events include collisions between motorists but may also include collisions with non-motorists (e.g., pedestrians and bicyclists). Prior research has linked and successfully used these data sources to examine a variety of research questions; additional details are available elsewhere (Goodwin et al., 2022).

We then linked additional county-level contextual information from several data sources. Sources included US Department of Agriculture's Rural-Urban Continuum Codes, County Health Rankings annual data, and the American Community Survey 5-year estimate tables. Variables from these national and publicly available datasets were linked using each individual's county of residence and the year of the alcohol-impaired driving event. County-level estimates from the closest available year were used when an estimate from the exact year of the impaired driving event was not available. Rural-Urban Continuum Codes are established every 10 years and reflect the urbanicity of each county in the US based on population and commuter criteria; they are categorized on a nine-point scale, including metropolitan and non-metropolitan categories (Office of Management and Budget, 2013; Economic Research Service, 2020). Urbanicity data were linked to individuals by county of residence, using 2003 urbanicity values for licensing-crash data between 2007 and 2012, and 2013 urbanicity values for licensing-crash data between 2013 and 2016. County Health Rankings data are obtained and collated from various sources (e.g., the Behavioral Risk Factor Surveillance System, the National Center for Health Statistics) and includes variables that reflect population health, such as percent reporting excessive drinking (Remington et al., 2015; University of Wisconsin Population Health Institute, 2021). In this analysis, County Health Rankings values were linked to licensing-crash data by county and year where available. For example, percent reporting excessive drinking data was available from 2012 to 2016, so for this variable, data were linked to individuals by county and year for licensing-crash data between 2012 and 2016, and linked by county using 2012 County Health Ranking values for licensing-crash data between 2007 and 2011. Finally, American Community Survey data are collected annually as part of the US Census and includes a variety of measures, including county-level social and demographic estimates (e.g., percent without health insurance) (US Census Bureau, 2017; National Research Council, 2007; Powers et al., 2015). Values for American Community Survey variables were linked to licensing-crash data by county and year for all data years. Detailed linkage procedures for these three data sources are described in greater detail elsewhere (Singichetti et al., XXXX).

2.2. Inclusion and exclusion criteria

We included individuals who were convicted of an alcohol-DWI and sustained a resulting driver's license suspension between 2007 and 2016. We included only individuals between the ages of 21 and 64 at the time of the impaired driving event. Individuals under the age of 21 were excluded as they are impacted by different alcohol-DWI policies (different blood alcohol content [BAC] cutoffs for alcohol-DWI charges), and individuals over the age of 64 were excluded due to changes in license renewal policies and average driving patterns. We excluded alcohol-DWI convictions associated with events where individuals refused to submit to a chemical test to check BAC levels, as their suspension trajectories differ greatly from others (i.e., automatic one-year suspension for refusal, after the immediate civil revocation and prior to conviction suspension).

When an individual is identified as driving while impaired by alcohol, they typically receive an automatic 30-day suspension known as a 'civil revocation'. Suspensions that are applied after an individual is convicted ('conviction suspension') can often begin months after the actual impaired driving event due to court caseloads and administrative processing times. We excluded any conviction suspensions for which a corresponding civil revocation could not be identified, as civil revocation records contain data reflecting individual and impaired driving event characteristics (e.g., age, date of event to determine whether a crash event happened at the same time).

2.3. Exposure and covariates

In NC alcohol-impaired driving policies, individuals who sustain an alcohol-DWI conviction for the first time in three years receive a 1-year license suspension, while individuals who sustain a second alcohol-DWI conviction within three years of the first, receive a 4-year license suspension. An additional suspension within seven years of the first suspension can result in permanent license revocation.

To understand the impact of license suspension duration on recidivism and crash outcomes, we used suspension type as a proxy for duration. In other words, we compared individuals who sustained initial suspensions with those who sustained repeat suspensions between 2007 and 2016. Type of index suspension (initial vs. repeat) in our data was determined using suspension description text available in NC licensing records. In this study, 'repeat suspension' only includes second convictions for individuals (within three years of first conviction) and does not include third or later suspensions. If an individual had multiple alcohol-DWI conviction suspensions during the study period, we only included the first observed conviction suspension as their index suspension. For example, individuals who sustained both an initial and repeat suspension during the study period were categorized based on the first observed suspension in our data – in this case, the initial suspension.

Personal and event-specific covariates considered in this study were obtained from licensing and crash data. Age at impaired driving event was calculated using an individual's date of birth and the date of an alcohol-DWI civil revocation event. Sex and race/ethnicity were collected in licensing data, with sex categorized as male or female, and race/ethnicity categorized as Asian, American Indian, Black, Hispanic, or White. Finally, crash status at index impaired driving event (yes/no) was determined via the linkage of licensing and crash data, using corresponding dates of civil revocation and crash events.

Seven county-level contextual characteristics were also considered in this study. A four-level urban–rural status variable was created based on Rural-Urban Continuum Codes (Metropolitan, Urban with population 20,000 or more, Urban with population 2,500 to 19,999, and Rural). Implementation of effective strategies to reduce alcohol-impaired driving and subsequent harms, such as sobriety checkpoints and alcohol treatment programs, varies by urbanicity. In addition, prior examinations of urbanicity have determined that rates of alcohol use are higher in urban areas compared to rural areas (Dixon and Chartier, 2016), and that rural alcohol-DWI offenders have a significantly higher risk of heavy alcohol use compared to urban offenders (Malek-Ahmadi and Degiorgio, 2015). County-level estimates for percent of the population without health insurance, percent living in poverty, and percent unemployed were obtained from the American Community Survey. Finally, the ratio of population to primary care physicians, percent of the population reporting excessive drinking, and a residential segregation

index were obtained from County Health Rankings data. Specifically, the Black/White residential segregation index measures the degree of geographic separation between Black and White residents in each county, and has been used in research as a proxy for structural racism (University of Wisconsin Population Health Institute, 2023). Index scores for this measure range from 0 (complete integration) to 100 (complete segregation).

2.4. Outcomes of interest

We examined two outcomes of interest in this study: alcohol-related license outcomes and crashes. Alcohol-related license outcomes were identified using a binary alcohol indicator variable that is recorded in the original suspension record, and included alcohol-DWI-related suspensions that were identified using suspension descriptions fields for each record (i.e., either civil revocation or conviction), refusal to complete a chemical test (i.e., BAC test refusal), and violation of an alcohol restriction (i.e., a restriction placed on an individual's license following license restoration after an alcohol-DWI conviction suspension that prohibits driving with an alcohol concentration of ≥ 0.04 or ≥ 0.00, based on an individual's conviction history). Crashes were identified using NC police-reported crash data, which includes information from crash reports completed by trained police officers immediately following the crash event. The start date of the first eligible license and crash outcomes for each individual in the study cohort was used to determine if the outcome occurred within the follow-up period of the individual's index suspension.

2.5. Statistical analysis

After identifying our cohort of individuals with an initial (1-year) or repeat (4-year) alcohol-DWI license conviction, we examined the distribution of personal and contextual characteristics overall and by suspension type. We calculated frequencies and percentages overall and by suspension type for each covariate. Continuous contextual covariates were categorized using quartiles.

Next, we assessed and confirmed the proportional hazards assumption using graphical and statistical methods. Specifically, we visually assessed log(-log) survival curves and observed parallel trends for the comparison groups, and we fit a model with time dependent covariates (interactions of log(time) and covariates) which produced non-significant results. After determining that our data met assumptions, we used Cox proportional hazards models to estimate hazard ratios (HRs) for each outcome. We calculated both overall unadjusted and adjusted HRs (aHRs) for the first occurrence of each of our two outcomes separately. Individuals were followed from the first day following the end of their license suspension through 3 years (1095 days). Individuals were censored 3 years after the end of their license suspension (end of follow-up) or on December 31, 2016 (administrative censoring), whichever came first. A 3-year follow-up period was used as it corresponds to the definition for assessing whether someone incurred a repeat suspension in NC policy. We produced unadjusted and adjusted Kaplan-Meier (KM) survival curves, stratified by exposure group, for each outcome of interest.

The final adjustment set for adjusted analyses was determined using a directed acyclic graph (DAG) to examine the complex relationships between the exposure, covariates, and outcomes of interest (Vander-Weele et al., 2008). The DAG in this study (Fig. A.1) was developed using personal individual-level covariates (e.g., age, sex) and contextual county-level characteristics (e.g., percent without health insurance, residential segregation) identified from a detailed literature review, and key relationships that may have impacted exposure and outcome

associations were considered for the final minimally sufficient adjustment set. This final adjustment set included the following variables: race/ethnicity, sex, residential segregation, urbanicity, crash involvement at index alcohol-impaired driving event, and year of index alcohol-impaired driving event. A functional form assessment was conducted for each continuous variable in the final adjustment set (i.e., residential segregation index and year of index impaired driving event) and quadratic forms were found to have the best fit and used in the adjusted models.

We assessed effect measure modification of the association between duration of index suspension and license and crash outcomes. We compared a model containing the final adjustment set with a model containing the adjustment set as well as an interaction term between the exposure and race/ethnicity variable, which yielded significant results. We examined estimates of the exposure-outcome association by racial/ethnic group, finding notable differences, and we present aHRs for each outcome stratified by groups of race/ethnicity.

Finally, a secondary analysis was conducted using a follow-up period of 5 years to examine outcomes beyond the original 3-year period. This allowed us to observe any potential sustained effects of suspension in our cohort and is important given few studies examining long-term effects of suspension beyond the look-back period established in policies.

All HRs in this study were calculated with corresponding 95 % confidence intervals (CIs). Differences in HRs were interpreted as percent higher/lower, using the following formula: *((1/HR)-1))*100*, and initial (1-year) suspensions were used as the reference group in all analyses. Analyses were conducted using SAS version 9.4, and this study was reviewed and approved by the Institutional Review Board of the lead author's institution (IRB # 22-0270).

3. Results

3.1. Demographic characteristics, overall and by exposure groups

The study population included 122,002 individuals who sustained at least one alcohol-DWI conviction suspension between 2007 and 2016, including 117,244 with initial (1-year) suspensions and 4,758 with repeat (4-year) suspensions. Table 1 includes personal and contextual characteristics included in the final adjustment set stratified by suspension duration, while Table A.1 includes additional characteristics that were examined but not included in the final adjustment set.

The number of overall suspensions among males was about 2.6 times that among females. The percentage of suspensions among males was slightly greater among repeat suspensions compared to initial (76.1 % vs 72.2 %). In both suspension types, the largest percentage of suspensions occurred among White individuals (initial: 72.3 %, repeat: 74.6 %), followed by Black individuals (initial: 20.6 %, repeat: 18.3 %). About 7 % of suspensions, overall and by type, were associated with a police-reported crash on the date of the index impaired driving event. The majority of initial and repeat suspensions occurred in metropolitan counties, with the percent of initial suspensions occurring among individuals in metropolitan areas slightly greater (73.4 %) than the percent of repeat suspensions (70.0 %). More than 40 % of initial and repeat suspensions occurred in counties with the highest residential segregation index scores (quartile 4).

3.2. Alcohol-related license outcomes

The adjusted KM survival curves for 3-year license outcomes (Fig. 1a) demonstrates the difference in survival trends for individuals with initial versus repeat index suspensions, after adjusting for potential confounding (see Fig. A.2 for unadjusted survival curves). Three years

Table 1

Selected personal and contextual characteristics* of individuals with at least one alcohol-DWI conviction in NC, 2007–2016.

Characteristic **	Overall Suspensions		Initial Suspensions		Repeat Suspensions	
	n	%	n	%	n	%
	122,002	–	117,244	96.1	4,758	3.9
Sex						
Female	33,768	27.7	32,629	27.8	1139	23.9
Male	88,224	72.3	84,606	72.2	3618	76.1
Race/ethnicity						
Asian	875	0.7	854	0.7	21	0.4
Black	24,552	20.5	23,680	20.6	872	18.6
Hispanic	6,629	5.5	6386	5.6	243	5.2
American Indian	1,002	0.8	948	0.8	54	1.2
White	86,581	72.4	83,090	72.3	3491	74.6
Crash at index alcohol impaired driving event						
Yes	8885	7.3	8580	7.3	305	6.4
No	113,117	92.72	108,664	92.7	4453	93.6
Urbanicity						
Metro area	87,717	73.3	84,568	73.4	3149	70.0
Urban area with population of 20,000 or more	19,188	16.0	18,355	15.9	833	18.5
Urban area with population of 2,500–19,999	9441	7.9	9052	7.9	389	8.6
Rural Area	3319	2.8	3190	2.8	129	2.9
Residential segregation index*						
Quartile 1: < 28	13,301	11.3	12,772	11.3	529	12.0
Quartile 2: 28 to < 36	15,299	13.0	14,717	13.0	582	13.2
Quartile 3: 36 to < 46	38,175	32.4	36,747	32.4	1428	32.4
Quartile 4: ≥ 46	50,951	43.3	49,087	43.3	1864	42.3

*Only variables included in the final adjustment set (except for year of impaired driving event) are presented here. See Supplemental Table 1 for distribution of other characteristics that were considered but not included in the adjusted analyses.

**Missingness: Sex < 0.01 %; Race/ethnicity = 1.9 %; Crash = 0 %; Urbanicity = 1.9 %; Residential segregation = 3.5 %.

***Residential Segregation was categorized into quartiles for interpretation here but was included as a continuous variable (modelled in the quadratic form per functional form analysis) in the final adjusted analyses.

following the end of the index suspension, the predicted risk of having an alcohol-related license outcome was about 8 % among individuals with an initial suspension versus nearly 5 % for individuals with a repeat suspension.

Relative to individuals exposed to an initial alcohol-DWI suspension, individuals with a repeat suspension had a decreased incidence of license outcomes in the 3 years immediately following the index suspension (Table 2). The aHR of the association between license duration and having a follow-up license outcome was 0.49 (95 % CI: 0.42, 0.57), indicating that the subsequent license outcome incidence was 103 % lower among individuals with a repeat compared to initial index suspension.

3.3. Crash outcomes

As demonstrated in Fig. 1b, adjusted KM survival curves for 3-year police-reported crash outcomes varied by exposure to either initial or repeat index suspension type (see Fig. A.1 for unadjusted survival curves). The predicted risk of having a crash outcome within 3 years of completing the index license suspension was almost 15 % among those exposed to an initial license suspension and nearly 10 % among those exposed to a repeat license suspension.

Similar to alcohol-related license outcomes, individuals with a repeat suspension had a decreased incidence of crash outcomes in the 3 years immediately following the index suspension (Table 2). Specifically, the incidence of a subsequent crash outcome was 49 % lower among individuals with repeat compared to initial index suspensions (aHR: 0.67; 95 % CI: 0.60, 0.75).

3.4. Modification by Race/Ethnicity

Assessment of modification for both outcomes of interest demonstrated that while repeat index suspensions were associated with a lower incidence of alcohol and crash outcomes compared to initial index suspensions, the magnitude of these associations varied by race/ethnicity (Table 3). Due to low numbers of outcomes among Asian, Hispanic, and American Indian individuals, stratum-specific estimates were only considered for Black and White individuals (race/ethnicity for each individual was obtained from licensing data). However, in Table A.2, we provide numbers of 3-year license and crash outcomes by all subgroups of race/ethnicity.

Estimates comparing individuals who were Black or White revealed that among Black individuals, the incidence of a subsequent license outcome was 162 % lower among those exposed to a repeat versus an index suspension (aHR: 0.38; 95 % CI: 0.26, 0.55), while for White individuals, the incidence was 87 % lower (aHR: 0.54; 95 % CI: 0.45, 0.64). A similar pattern was observed for crash outcomes, where crash incidence for repeat versus initial suspensions among Black individuals was 56 % lower (aHR: 0.64; 95 % CI: 0.50, 0.83), while only 39 % lower among White individuals (aHR: 0.72; 95 % CI: 0.63, 0.81).

Adjusted and unadjusted KM survival curves for both outcomes, stratified by index suspension type and race/ethnicity (Black and White) are presented in Fig. 2 and Fig. A.3, respectively. For both outcomes, survival curves for initial suspensions were notably different by race, while curves for repeat suspensions were relatively similar by race. The predicted risk of having a license outcome within 3 years of an initial suspension was over 10 % among Black individuals and about 8 % among White individuals (Fig. 2a). For crash outcomes following an initial suspension, the predicted risks were about 17 % and 14 % among Black and White individuals, respectively (Fig. 2b). For both outcomes following repeat suspension, predicted risks for Black and White individuals were within 1 % of each other.

3.5. Secondary analyses

The secondary analyses of associations between suspension type and license and crash outcomes using a 5-year follow-up period yielded results similar to those of the primary analysis in terms of direction, with decreased incidence of outcomes among individuals exposed to a repeat suspension compared to those exposed to an initial suspension (Table A.3). Although aHRs for 3-year and 5-year license outcomes remained similar (3-year aHR: 0.49; 5-year aHR: 0.50), a greater difference was observed between crash outcomes by length of follow-up period (3-year aHR: 0.67; 5-year aHR: 0.74).

A comparison of stratum-specific estimates by race/ethnicity for 5-year outcomes also yielded results similar to those of 3-year outcomes, with considerable differences between the aHRs for Black and White individuals. Adjusted KM survival curves, stratified by index suspension type only, and by index suspension type and race/ethnicity, are
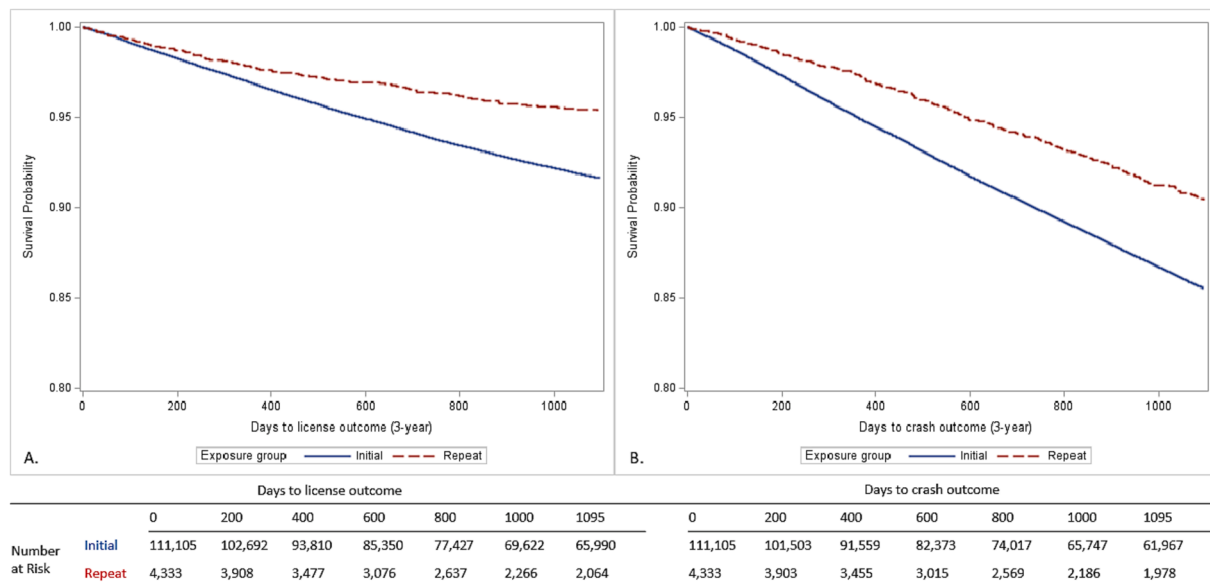
Fig. 1. Adjusted Kaplan-Meier survival curves for license and crash outcomes, stratified by suspension type (initial or repeat).

		Days to license outcome							Days to crash outcome						
		0	200	400	600	800	1000	1095	0	200	400	600	800	1000	1095
Number at Risk	Initial	111,105	102,692	93,810	85,350	77,427	69,622	65,990	111,105	101,503	91,559	82,373	74,017	65,747	61,967
	Repeat	4,333	3,908	3,477	3,076	2,637	2,266	2,064	4,333	3,903	3,455	3,015	2,569	2,186	1,978

Table 2

Unadjusted and adjusted* overall hazard ratios for the association between duration of alcohol-DWI conviction suspension and first occurrence of alcohol-related license outcomes and crash outcomes in NC, 2007–2016.

	Number of events	Unadjusted HR (95 % CI)	Adjusted HR (95 % CI)
License	9,001		
Initial	8,816	1.00 (ref)	1.00 (ref)
Repeat	185	0.55 (0.48, 0.64)	0.49 (0.42, 0.57)
Crash	15,355		
Initial	14,996	1.00 (ref)	1.00 (ref)
Repeat	359	0.62 (0.56, 0.69)	0.67 (0.60, 0.75)

*Adjusted for race/ethnicity, sex, crash at index impaired driving event, urbanicity, residential segregation index, and year of index impaired driving event.

presented in Figs. A.4 and A.5, respectively.

4. Discussion

This study considered alcohol-impaired driving-related license and police-reported crash outcomes among individuals who experienced an initial or repeat alcohol-DWI conviction license suspension. HRs indicated decreased incidence of both outcomes among individuals with repeat versus initial index suspensions. Stratum-specific HRs suggested this decreased incidence of outcomes among repeat versus initial index suspensions was greater in magnitude among Black individuals compared to White individuals. This is among the first studies to examine impacts of different durations of conviction-related license suspension and to stratify those impacts by race/ethnicity, which is especially important given current increases in impaired driving-related behavior and crashes.

The differences between initial and repeat suspensions observed in this study may be explained by several critical factors. First, this difference may be a reflection of other barriers to mobility, such as difficulty in reinstating licensure. This process requires paying a reinstatement fee to the NC Department of Motor Vehicles and proof of auto insurance, where costs often increase significantly for individuals after sustaining a DWI conviction. NC has the highest observed average annual auto insurance costs of all US states, with an increase of about 266 % following conviction of an alcohol-DWI (Gusner, 2023). Therefore, although an individual may successfully complete an alcohol-DWI conviction suspension, they may not reinstate their license due to the associated expenses established in the current system.

Second, in addition to these economic barriers to reinstating licensure, the lower incidence of outcomes following repeat versus initial index suspensions may be due to changes in driving behavior and frequency. In particular, individuals with a repeat suspension are one step closer to sustaining a permanent license revocation, which is the

Table 3

Stratum-specific* unadjusted and adjusted** hazard ratios for the association between duration of alcohol-DWI conviction suspension and first occurrence of alcohol-related license outcomes and crash outcomes by race/ethnicity in NC, 2007 – 2016.

	Black			White		
	Number of events	Unadjusted HRs (95 % CI)	Adjusted HRs (95 % CI)	Number of events	Unadjusted HRs (95 % CI)	Adjusted HRs (95 % CI)
License						
Initial	2,070	1.00 (ref)	1.00 (ref)	6,030	1.00 (ref)	1.00 (ref)
Repeat	31	0.42 (0.31, 0.63)	0.38 (0.26, 0.55)	142	0.60 (0.51, 0.71)	0.54 (0.45, 0.64)
Crash						
Initial	3,277	1.00 (ref)	1.00 (ref)	10,224	1.00 (ref)	1.00 (ref)
Repeat	65	0.58 (0.45, 0.74)	0.64 (0.50, 0.83)	271	0.67 (0.60, 0.76)	0.72 (0.63, 0.81)

*Stratum-specific estimates for American Indian, Asian, and Hispanic individuals not presented due to the low numbers of outcomes in these groups.
**Adjusted for race/ethnicity, sex, crash at index impaired driving event, urbanicity, residential segregation index, and year of index impaired driving event.
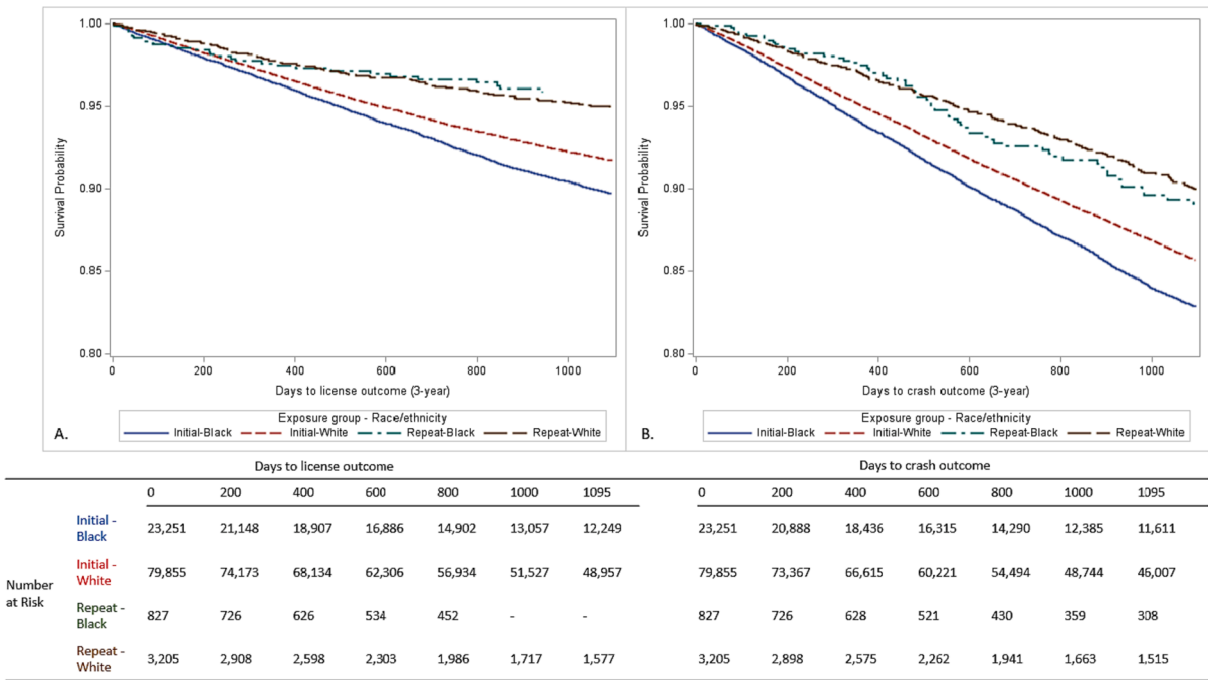
Fig. 2. Adjusted Kaplan-Meier survival curves for license and crash outcomes, stratified by suspension type (initial or repeat) and race/ethnicity (Black or White).

consequence of a third DWI conviction in NC. Restoring a driver's license after a permanent revocation can be even more difficult, as individuals must wait a minimum of three years before they can be considered for a conditional license restoration. Therefore, the possibility of license revocation with another conviction may reduce driving frequency and/or risky driving behavior among individuals in the repeat index suspension group.

Third and relatedly, the longer suspension period may have resulted in livelihood and lifestyle changes for the suspended individual that carry through the post-suspension period, such as switching to other forms of transportation or other housing/employment arrangements to minimize the need for a personal vehicle. Regardless of whether these changes are made by choice or due to circumstances, such changes are particularly difficult in NC and most of the US, where land use patterns and transportation systems have created a strong dependence on motor vehicles. Such environments can make accessing essential services, such as housing, healthcare, and employment, extremely difficult for those without access to a personal vehicle (Crozier and Garrett, 2019; Syed et al., 2013; Wolfe et al., 2020; Lichtenwalter et al., 2006; Fletcher et al., 2010; Browne et al., 2016).

Taken together, alcohol-impaired driving and associated convictions are likely the result of a complex relationship between numerous factors, such as engagement in risky driving behavior and access to a personal vehicle versus alternate transportation options, as well as traffic enforcement patterns and profiling and charges and sentencing patterns for traffic-related violations – all of which are well-documented to differ by race and ethnicity. Prior research has estimated that Black non-Hispanic individuals have less access to a personal vehicle, have shorter trips, and travel less (based on annual vehicle miles traveled per driver) compared to White non-Hispanic individuals in NC (Fliss, 2019). National estimates also indicate that Black non-Hispanic individuals are less likely to use personal vehicles and more likely to utilize public transportation for commutes than White non-Hispanic individuals (McKenzie, 2015). However, findings from multiple prior studies using different data sources conclude that compared to White individuals, Black individuals are more likely to experience a traffic stop and subsequent search, and have higher rates of alcohol-DWI arrests,

sentencing, and conviction (Singichetti et al., XXXX; Baumgartner et al., 2017; Roh and Robinson, 2009; Crozier and Garrett, 2019; Pierson et al., 2020; Baumgartner et al., 2018; Warren et al., 2006), consistent with the differences observed in our study. Taken together, these contrasts may suggest that differences observed in this study may be the result of disparities that exist along the path from baseline driving opportunity, likelihood of identification at traffic stops, sentencing, and potential license reinstatement barriers, among other factors.

Limitations.

This study used an open cohort, meaning individuals could enter or leave the cohort at any time, and we could not determine from our data if and when an individual left our cohort (e.g., moved out of state). However, it is expected these fluctuations do not vary by exposure group and therefore would not bias results. Second, there may be potential sources of uncontrolled confounding in this analysis. We do not know how frequently licensed individuals are driving while impaired at baseline and we do not know where and how frequently enforcement patterns are implemented throughout NC, which impacts individual drivers' potential for the exposure and the outcome. Third, we did not consider suspensions due to other, non-alcohol-related convictions as competing events for alcohol-DWI suspensions in this analysis. Individuals may be more cautious about driving after receiving a suspension or driving while suspended (Hagen et al., 1980; Ross and Gonzales, 1988); however, prior research has shown that large percentages of individuals continue to drive while suspended (McCartt et al., 2003; Wells-Parker and Cosby, 1988; Hagen et al., 1980; Ross and Gonzales, 1988) and may still be involved in driving outcomes such as crashes (DeYoung et al., 1997). Fourth, crash outcomes considered in this study were based on any involvement in an MVC and do not allow us to draw any conclusions regarding an individual's responsibility for a crash. Finally, we only had data on suspension end dates and not license reinstatement, which are two distinct and separate changes to licensure. The latter requires proof of insurance and may be a barrier to post-conviction driving exposure that could not be addressed in this study.

5. Future research priorities

The personal and contextual characteristics considered in this study represent only a small piece of the larger body of risk factors that could contribute to alcohol-DWI convictions, suspensions, and license and crash outcomes. Future research should examine this issue more broadly, using a social and structural determinants of health framework to explore the underlying mechanisms that lead to initial and repeat alcohol-impaired driving behaviors, as well as the impact of public-health informed interventions on reducing impaired driving behaviors. Studies could examine the role of substance use disorder treatment access, limited driving privilege allowances, and other public health-informed interventions (e.g., peer support programming, specialty DWI courts) on recidivism and crash outcomes. For example, one study of administrative NC court data found that enrolling in and completing a specialty DWI court program focused on treatment and recovery was effective at preventing repeat DWI arrests and convictions (Sloan et al., 2016).

In addition, future work should carefully examine factors that influence post-suspension driving patterns, such as the ability to reinstate licensure after an alcohol-DWI conviction due to NC DMV fees and increased auto insurance rates, as well as access to alternate transportation options. Although lack of licensure may have positive impacts on road safety by reducing MVCs and injuries, broader impacts of reduced mobility on public health, in terms of access to employment, healthcare, and food, must be examined in greater detail. Partnership across disciplines may facilitate a more holistic assessment of these impacts to ensure that interventions for mitigating alcohol-impaired driving maximize all critical public health outcomes (e.g., road safety, access to healthcare). Finally, future research should continue to include an emphasis on assessments of equity, particularly by race/ethnicity given prior documented differences, to monitor future potential disparities and support the continued improvement and development of interventions that are both equitable and effective for all drivers.

6. Conclusions

This study examined the impact of suspension duration on license and crash outcomes among individuals who experienced an alcohol-DWI conviction in NC between 2007 and 2016. We observed decreased incidence of license- and crash-related outcomes following repeat suspension compared to initial suspension, with a stronger association among Black individuals compared to White individuals. These findings should be interpreted as only one part of a larger and complex series of events and circumstances that collectively influence alcohol-impaired driving, suspensions, crashes, and other public health-related outcomes (e.g., access to essential services). Future research should continue to examine these factors and explore the holistic effectiveness of interventions to reduce harmful road safety outcomes, while also maximizing other beneficial public health outcomes (e.g., access to healthcare, employment).

CRediT authorship contribution statement

Bhavna Singichetti: Conceptualization, Formal analysis, Funding acquisition, Investigation, Visualization, Writing – original draft, Methodology. **Yvonne M. Golightly:** Conceptualization, Methodology, Writing – review & editing. **Yudan Chen Wang:** Conceptualization, Data curation, Methodology, Writing – review & editing. **Stephen W. Marshall:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Rebecca B. Naumann:** Conceptualization, Funding acquisition, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The data that has been used is confidential.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.aap.2023.107449.

References

Ahlin, E.M., Zador, P.L., Rauch, W.J., Howard, J.M., Duncan, G.D., 2011. First-time DWI offenders are at risk of recidivating regardless of sanctions imposed. J. Crim. Just. 39 (2), 137–142. https://doi.org/10.1016/j.jcrimjus.2011.01.001.

Baumgartner, F.R., Christiani, L., Epp, D.A., Roach, K., Shoub, K., 2017. Racial disparities in traffic stop outcomes. Duke FL Soc. Change 9, 21.

Baumgartner, F.R., Epp, D.A., Shoub, K., 2018. Suspect Citizens: What 20 Million Traffic Stops Tell Us about Policing and Race. Cambridge University Press.

Bell v. Burson, 402 U.S. 535.(US Supreme Court 1971).

Blincoe L., Miller T.R., Wang J.S., et al. 2022. *The Economic and Societal Impact of Motor Vehicle Crashes, 2019.* National Highway Traffic Safety Administration.

Bouffard, J.A., Niebuhr, N., Exum, M.L., 2017. Examining specific deterrence effects on DWI among serious offenders. Crime Delinquency 63 (14), 1923–1945. https://doi.org/10.1177/0011128716675359.

Brar, S.S., 2012. Estimation of Fatal Crash Rates for Suspended/Revoked and Unlicensed Drivers in California. California Department of Motor Vehicles, Research and Development Branch.

Browne, T., Priester, M.A., Clone, S., Iachini, A., DeHart, D., Hock, R., 2016. Barriers and facilitators to substance use treatment in the rural south: A qualitative study. J. Rural Health 32 (1), 92–101. https://doi.org/10.1111/jrh.12129.

Caetano, R., McGrath, C., 2005. Driving under the influence (DUI) among U.S. ethnic groups. Accid. Anal. Prev. 37 (2), 217–224. https://doi.org/10.1016/j.aap.2004.07.004.

Centers for Disease Control and Prevention. Public Health Professionals Gateway - Motor Vehicle Injury. Published November 12, 2019. Accessed September 13, 2020. https://www.cdc.gov/publichealthgateway/didyouknow/topic/vehicle.html.

Centers for Disease Control and Prevention, National Center for Injury Prevention and Control. Impaired Driving: Get the Facts. Published December 28, 20222. Accessed January 27, 2023. https://www.cdc.gov/transportationsafety/impaired_driving/impaired-drv_factsheet.html.

Crozier, W.E., Garrett, B.L., 2019. Driven to failure: An empirical analysis of driver's license suspension in North Carolina. Duke LJ 69, 1585.

Crozier, W.E., Garrett, B.L., Modjadidi, K., 2022. Understanding the impact of driver's license suspension: Lay opinion in impacted and non-impacted populations. Justice Eval. J. 5 (2), 186–207. https://doi.org/10.1080/24751979.2021.1976596.

DeYoung, D.J., 1997. An evaluation of the effectiveness of alcohol treatment, driver license actions and jail terms in reducing drunk driving recidivism in California. Addiction 92 (8), 989–997. https://doi.org/10.1111/j.1360-0443.1997.tb02978.x.

DeYoung, D.J., Gebers, M.A., 2004. An examination of the characteristics and traffic risks of drivers suspended/revoked for different reasons. J. Saf. Res. 35 (3), 287–295. https://doi.org/10.1016/j.jsr.2004.01.002.

DeYoung, D.J., Peck, R.C., Helander, C.J., 1997. Estimating the exposure and fatal crash rates of suspended/revoked and unlicensed drivers in California. Accid. Anal. Prev. 29 (1), 17–23. https://doi.org/10.1016/S0001-4575(96)00056-5.

DeYoung D.J. 2011. Traffic safety impact of judicial and administrative driver license suspension. In: *Countermeasures to Address Impaired Driving Offenders.* Transportation Research Board; 41–53.

Division of Motor Vehicles, North Carolina Department of Transportation. DMV-349 Instructional Manual. Accessed February 3, 2023. https://connect.ncdot.gov/business/DMV/DMV%20Documents/DMV-349%20Instructional%20Manual.pdf.

Dixon, M.A., Chartier, K.G., 2016. Alcohol use patterns among urban and rural residents: demographic and social influences. Alcohol Res Curr Rev. 38 (1), 69–77.

Economic Research Service, US Department of Agriculture. USDA ERS - Rural-Urban Continuum Codes. Published December 10, 2020. Accessed December 8, 2021. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes/.

Elder, R.W., Voas, R., Beirness, D., et al., 2011. Effectiveness of ignition interlocks for preventing alcohol-impaired driving and alcohol-related crashes: A community guide systematic review. Am. J. Prev. Med. 40 (3), 362–376. https://doi.org/10.1016/j.amepre.2010.11.012.

Fell, J.C., 2014. Update: Repeat DWI offenders involvement in fatal crashes in 2010. Traffic Inj. Prev. 15 (5), 431–433. https://doi.org/10.1080/15389588.2013.838230.

Fell, J.C., 2019. Approaches for reducing alcohol-impaired driving: evidence-based legislation, law enforcement strategies, sanctions, and alcohol-control policies. Forensic Sci. Rev. 31 (2), 161–184.

Ferguson, S.A., 2012. Alcohol-impaired driving in the United States: contributors to the problem and effective countermeasures. Traffic Inj. Prev. 13 (5), 427–441. https://doi.org/10.1080/15389588.2012.656858.

Fletcher, C.N., Garasky, S.B., Jensen, H.H., Nielsen, R.B., 2010. Transportation access: A key employment barrier for rural low-income families. J. Poverty 14 (2), 123–144. https://doi.org/10.1080/10875541003711581.

Fliss, M.D., 2019. Racial disparities in law enforcement traffic stops: measurement, interpretation, & intervention possibilities. Dissertation. University of North Carolina at Chapel Hill. https://www.proquest.com/docview/2296129541?pq-origsite=gscholar&fromopenview=true.

Goodwin, A.H., Wang, Y.C., Foss, R.D., Kirley, B., 2022. The role of inexperience in motorcycle crashes among novice and returning motorcycle riders. J. Saf. Res. 82, 371–375. https://doi.org/10.1016/j.jsr.2022.07.003.

Gusner. P. 2023. How Much Do Car Insurance Rates Go Up After A DUI? Forbes Advisor. Published January 23, 2023. Accessed February 7, 2023. https://www.forbes.com/advisor/car-insurance/rate-increase-after-dui/.

Hagen, R.E., Williams, R.L., McConnell, E.J., 1979. The traffic safety impact of alcohol abuse treatment as an alternative to mandated licensing controls. Accid. Anal. Prev. 11 (4), 275–291. https://doi.org/10.1016/0001-4575(79)90054-X.

Hagen, R.E., McConnell, E.J., Williams, R.L., 1980. Suspension and Revocation Effects on the DUI Offender. Department of Motor Vehicles, Sacramento, California.

Hagen, R.E. 1977. Effectiveness of License Suspension or Revocation for Drivers Convicted of Multiple Driving-under-the-Influence Offenses. Department of Motor Vehicles.

Impinen, A., Rahkonen, O., Karjalainen, K., Lintonen, T., Lillsunde, P., Ostamo, A., 2009. Substance use as a predictor of driving under the influence (DUI) rearrests: A 15-year retrospective study. Traffic Inj. Prev. 10 (3), 220–226. https://doi.org/10.1080/15389580902822725.

Insurance Institute for Highway Safety, Highway Loss Data Institute, 2022. Fatality Facts 2020: Alcohol. IIHS-HLDI crash testing and highway safety. Published May 2022. Accessed January 29, 2023. https://www.iihs.org/topics/fatality-statistics/detail/alcohol.

Kagawa, R.M.C., McCort, C.D., Schleimer, J., et al., 2021. Racial bias and DUI enforcement: Comparing conviction rates with frequency of behavior. Criminol. Public Policy 20 (4), 645–663. https://doi.org/10.1111/1745-9133.12558.

Klein, T.M., 1989. Changes in Alcohol-Involved Fatal Crashes Associated with Tougher State Alcohol Legislation. National Highway Traffic Safety Administration, United States.

Lechner, J.M., Wicclair, B.L., 2021. Driven to despair: Confronting racial inequity in North Carolina's license suspension practices. Campbell Law Rev. 43 (2), 21.

Lichtenwalter, S., Koeske, G., Sales, E., 2006. Examining transportation and employment outcomes: Evidence for moving beyond the bus pass. J. Poverty 10 (1), 93–115. https://doi.org/10.1300/J134v10n01_05.

Malek-Ahmadi, M., Degiorgio, L., 2015. Risk of alcohol abuse in urban versus rural DUI offenders. Am. J. Drug Alcohol Abuse 41 (4), 353–357. https://doi.org/10.3109/00952990.2015.1043436.

Mann, R.E., Smart, R.G., Stoduto, G., et al., 2000. Changing drinking-and-driving behaviour: the effects of Ontario's administrative driver's licence suspension law. Can. Med. Assoc. J. 162 (8), 1141–1142.

McCartt, A.T., Geary, L.L., Berning, A., 2003. Observational study of the extent of driving while suspended for alcohol impaired driving. Inj. Prev. 9 (2), 133–137. https://doi.org/10.1136/ip.9.2.133.

McKenzie, B., 2015. Who Drives to Work?: Commuting by Automobile in the United States: 2013. US Department of Commerce, Economics and Statistics Administration, US Census Bureau.

Miller, P.G., Curtis, A., Sønderlund, A., Day, A., Droste, N., 2015. Effectiveness of interventions for convicted DUI offenders in reducing recidivism: a systematic review of the peer-reviewed scientific literature. Am. J. Drug Alcohol Abuse 41 (1), 16–29. https://doi.org/10.3109/00952990.2014.966199.

Mughan, S., Carroll, J., 2021. Escaping the long arm of the law? Racial disparities in the effect of drivers' license suspensions on offense probabilities. South. Econ. J. 87 (4), 1366–1389. https://doi.org/10.1002/soej.12486.

National Highway Traffic Safety Administration. A Guide to Sentencing DWI Offenders. US Department of Transportation; 2005:44. https://pubs.niaaa.nih.gov/publications/SentencingDWI/A_Guide2.pdf.

National Highway Traffic Safety Administration. 2008. Traffic Safety Facts - Laws: Repeat Intoxicated Driver Laws. U.S. Department of Transportation; Accessed October 7, 2021. https://www.nhtsa.gov/sites/nhtsa.gov/files/810879.pdf.

National Highway Traffic Safety Administration. Traffic Safety Facts 2020 Data: Alcohol-Impaired Driving. US Department of Transportation; 2022. Accessed January 27, 202https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/813294.

National Research Council. 2007. Using the American Community Survey: Benefits and Challenges. National Academies Press; Accessed November 22, 2021. http://ebookcentral.proquest.com/lib/unc/detail.action?docID=3378276.

NC First Commission. 2019. Rural Transportation Issues in North Carolina. North Carolina Department of Transportation; Accessed February 7, 2023. https://www.ncdot.gov/about-us/how-we-operate/finance-budget/nc-first/Documents/nc-first-brief-edition-4.pdf.

Nichols, J.L., Ross, H.L., 1990. The effectiveness of legal sanctions in dealing with drinking drivers. Alcohol Drugs Driv. 6 (2), 33–60.

Office of Management and Budget. 2013. Revised Delineations of Metropolitan Statistical Areas, Micropolitan Statistical Areas, and Combined Statistical Areas, and Guidance on Uses of the Delineations of These Areas. Office of Management and Budget; Accessed December 8, 2021. https://obamawhitehouse.archives.gov/sites/default/files/omb/bulletins/2013/b-13-01.pdf.

Oh, S., Vaughn, M.G., Salas-Wright, C.P., AbiNader, M.A., Sanchez, M., 2020. Driving under the influence of alcohol: Findings from the NSDUH, 2002–2017. Addict. Behav. 108, 106439 https://doi.org/10.1016/j.addbeh.2020.106439.

Peck, R.C., 1991. The general and specific deterrent effects of DUI sanctions: A review of California's experience. Alcohol Drugs Driv.

Peck, R.C., Sadler, D.D., Perrine, M.W., 1985. The comparative effectiveness of alcohol rehabilitation and licensing control actions for drunk driving offenders: A review of the literature. Alcohol Drugs Driv. 1 (4), 15–39.

Pierson, E., Simoiu, C., Overgoor, J., et al., 2020. A large-scale analysis of racial disparities in police stops across the United States. Nat. Hum. Behav. 4 (7), 736–745. https://doi.org/10.1038/s41562-020-0858-1.

Powers, R., Beede, D.N., Telles, R., 2015. The Value of the American Community Survey: Smart Government, Competitive Businesses, and Informed Citizens. US Department of Commerce, Economics and Statistics Administration, p. 48.

Remington, P.L., Catlin, B.B., Gennuso, K.P., 2015. The County Health Rankings: rationale and methods. Popul. Health Metr. 13 (1), 11. https://doi.org/10.1186/s12963-015-0044-2.

Roh, S., Robinson, M., 2009. A geographic approach to racial profiling: The microanalysis and macroanalysis of racial disparity in traffic stops. Police Q. 12 (2), 137–169. https://doi.org/10.1177/1098611109332422.

Romano, E., Voas, R.B., Lacey, J.H., 2010. Alcohol and Highway Safety: Special Report on Race/Ethnicity and Impaired Driving. National Highway Traffic Safety Administration.

Ross, H.L., Gonzales, P., 1988. Effects of license revocation on drunk-driving offenders. Accid. Anal. Prev. 20 (5), 379–391. https://doi.org/10.1016/0001-4575(88)90020-6.

Sadler, D.D., Perrine, M.W., Peck, R.C., 1991. The long-term traffic safety impact of a pilot alcohol abuse treatment as an alternative to license suspensions. Accid. Anal. Prev. 23 (4), 203–224. https://doi.org/10.1016/0001-4575(91)90001-l.

Singichetti, B., Wang, Y.C., Golightly, Y.M., Marshall, S.W., Naumann, R.B. Unpublished Results. Trends and Disparities in Alcohol-DWI Suspensions by Suspension Duration, North Carolina, 2007-2016.

Sloan, F.A., Gifford, E.J., Eldred, L.M., McCutchan, S.A., 2016. Does the probability of DWI arrest fall following participation in DWI and hybrid drug treatment court programs? Accid. Anal. Prev. 97, 197–205. https://doi.org/10.1016/j.aap.2016.08.029.

Substance Abuse and Mental Health Services Administration (SAMHSA). 2022. 2020 NSDUH Detailed Tables. U.S. Department of Health and Human Services.

Syed, S.T., Gerber, B.S., Sharp, L.K., 2013. Traveling towards disease: transportation barriers to health care access. J. Commun. Health 38 (5), 976–993. https://doi.org/10.1007/s10900-013-9681-1.

Tashima, H.N., Marelich, W.D., 1989. A Comparison of the Relative Effectiveness of Alternative Sanctions for DUI Offenders: Development of a DUI Accident and Recidivism Tracking System, Vol. 1. Department of Motor Vehicles, Sacramento, California.

Taxman, F.S., Piquero, A., 1998. On preventing drunk driving recidivism: an examination of rehabilitation and punishment approaches. J Crim Justice. 26 (2), 129–143. https://doi.org/10.1016/S0047-2352(97)00075-5.

University of Wisconsin Population Health Institute. Explore Health Rankings. County Health Rankings & Roadmaps. Published 2021. Accessed December 8, 2021. https://www.countyhealthrankings.org/explore-health-rankings.

University of Wisconsin Population Health Institute. Residential Segregation - Black/White. County Health Rankings & Roadmaps. Accessed December 2, 2023. https://www.countyhealthrankings.org/explore-health-rankings/county-health-rankings-model/health-factors/social-economic-factors/family-and-social-support/residential-segregation-blackwhite.

US Census Bureau. American Community Survey Information Guide. Published online December 2017. Accessed November 18, 2021. https://www.census.gov/content/dam/Census/programs-surveys/acs/about/ACS_Information_Guide.pdf.

VanderWeele, T.J., Hernán, M.A., Robins, J.M., 2008. Causal directed acyclic graphs and the direction of unmeasured confounding bias. Epidemiology 19 (5). https://doi.org/10.1097/EDE.0b013e3181810e29.

Venkatraman, V., Richard, C.M., Magee, K., Johnson, K. 2021. Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices, 10th Edition, 2020. National Highway Traffic Safety Administration.

Voas, R.B., Tippetts, A.S., Fell, J.C., 2000. The relationship of alcohol safety laws to drinking drivers in fatal crashes. Accid. Anal. Prev. 32 (4), 483–492. https://doi.org/10.1016/S0001-4575(99)00063-9.

Voas, R.B., Tippetts, A.S., Taylor, E., 2000. Effectiveness of the Ohio Vehicle Action and Administrative License Suspension Laws. National Highway Traffic Safety Administration, United States.

Wagenaar, A.C., Maldonado-Molina, M.M., 2007. Effects of drivers' license suspension policies on alcohol-related crash involvement: long-term follow-up in forty-six states. Alcohol. Clin. Exp. Res. 31 (8), 1399–1406. https://doi.org/10.1111/j.1530-0277.2007.00441.x.

Wagenaar, A.C., Zobek, T., Williams, G., Hingson, R., 2000. Effects of DWI control efforts: a systematic review of the literature from 1960–1991. Minneap MN Univ Minn Sch Public Health.

Warren, P., Tomaskovic-Devey, D., Smith, W., Zingraff, M., Mason, M., 2006. Driving while black: bias processes and racial disparity in police stops. Criminology 44 (3), 709–738. https://doi.org/10.1111/j.1745-9125.2006.00061.x.

Warren-Kigenyi, N., Coleman, H., 2014. *DWI Recidivism in the United States: An Examination of State-Level Driver Data and the Effect of Look-Back Periods on Recidivism Prevalence.* National Highway Traffic Safety Administration, U.S. Department of Transportation, p. 9.

Wells-Parker, E., Cosby, P.J., 1988. Behavioral and employment consequences of driver's license suspension for drinking driving offenders. J. Saf. Res. 19 (1), 5–20. https://doi.org/10.1016/0022-4375(88)90028-X.

Willis, C., Lybrand, S., Bellamy, N., 2004. Alcohol ignition interlock programmes for reducing drink driving recidivism. Cochrane Database Syst. Rev. (3) https://doi.org/10.1002/14651858.CD004168.pub2.

Wolfe, M.K., McDonald, N.C., Holmes, G.M., 2020. Transportation barriers to health care in the United States: Findings from the National Health Interview Survey, 1997–2017. Am. J. Public Health 110 (6), 815–822. https://doi.org/10.2105/AJPH.2020.305579.