Approaches for Reducing Alcohol-Impaired Driving: Evidence-Based Legislation, Law Enforcement Strategies, Sanctions, and Alcohol-Control Policies

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TABLE OF CONTENTS

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ABSTRACT: Reducing impaired driving requires a systematic, consistent, and multifaceted approach. There is strong evidence on the effectiveness of both direct and indirect measures. The strategy that has the most immediate and largest impact has been highly publicized, visible, and frequent impaired-driving enforcement, especially deploying sobriety checkpoints or random breath testing. Lowering legal blood alcohol concentration (BAC) limits for driving to 0.05 g/dL or lower has also had a world-wide impact. Raising the legal drinking age has been successful in the US and other countries in reducing young impaired-driver fatal crashes. Graduated drivers' licensing for youth has also been effective by restricting conditions under which youth can drive. Sanctions that reduce impaired-driving recidivism include special driving-under-the-influence (DUI)/driving-while-intoxicated (DWI) courts, mandatory alcohol ignition interlocks, and consistent alcohol-monitoring programs. Opportunities for further progress include better enforcement of the drinking age and refusing to serve obviously intoxicated patrons. Technology for detecting alcohol impairment and autonomous vehicles will also play an important role in future efforts to eliminate impaired driving.

KEYWORDS: Alcohol-impaired driving, blood alcohol concentration (BAC), minimum legal drinking age, random breath testing (RBT), sobriety checkpoints.

FOREWORD

This article presents an overview of evidence-based policies and programs designed to reduce highway crashes involving alcohol-impaired drivers. Scholars, researchers, or practitioners with an interest in this area should also consult the article by Voas [181], and a report published by the US National Highway Traffic Safety Administration (NHTSA) [70] on "Countermeasures That Work", which lists over 100 specific traffic-safety countermeasures with evidence of effectiveness, covering all areas of traffic-safety behavioral programs. The latest in the series of NHTSA Alcohol and Highway Safety reviews also presents evidence up through 2006 [187]. Other articles relevant to this review include "Effectiveness of Behavioral Highway Safety Countermeasures" [146], "Preventing Impaired Driving: Opportunities and Problems" [182], and "Programs and Policies Designed to Reduce Impaired Driving" [183].

This article uses the public health approach taken by Voas [183], which provides a good logical structure for understanding the characteristics and impacts of alternative approaches. Alcohol-impaired driving countermeasures that are proven effective or that have great potential are classified here under three headings: Primary Prevention, Secondary Prevention, and Tertiary Prevention. Primary Prevention countermeasures reduce high-risk drinking and high-risk driving directly, by limiting alcohol availability and reducing high-risk nighttime driving. Secondary

Prevention countermeasures are intended to deter alcohol-impaired driving by adopting and enforcing effective impaired-driving laws. Tertiary Prevention focuses on countermeasures directed at preventing recidivism by convicted impaired-driving offenders, and include license and vehicle actions, treatment and rehabilitation programs, and alcohol-monitoring programs. The research described in this article primarily concerns the US, although a few international approaches are considered.

INTRODUCTION

Impaired Driving: A Worldwide Problem

Alcohol-impaired driving has been recognized as a problem almost as long as automobiles have existed [36]. Worldwide, it is estimated that alcohol-impaired driving crashes account for anywhere from 5% (e.g., Turkey, Nicaragua) to 35% (e.g., US, Australia) of the 1.35 million traffic deaths each year. A previous article, covering "International Trends in Alcohol and Drug Use Among Motor Vehicle Drivers," presents detailed evidence on the prevalence of alcohol-impaired driving in several different countries [24].

The World Health Organization (WHO) recommended four policies to reduce impaired driving in their 2018 report on the global status of road safety [209]:

- Adoption of a national drink-driving law;
- Setting blood alcohol concentration (BAC) limits for

adult drivers at 0.05 g/dL or lower;
- Setting zero-alcohol limits for young novice drivers; and
- Conducting random breath testing (RBT) programs similar to those developed in Australia as a key enforcement strategy.

This article covers all four of these evidence-based recommendations, and goes beyond these basic strategies to consider additional approaches. A brief overview of the alcohol-impaired driving problem in the US is presented in the remainder of this introduction below, with detailed evidence on potential countermeasures provided in the following sections of the article.

Numerous laboratory and simulator studies have shown that impairment in driving performance begins with the first drink (a BAC = .02 g/dL) and increases substantially with each subsequent one. The risk of a crash is significant beginning at .04–.05 g/dL BAC, and increases exponentially as BAC rises. Lowering the BAC limit to .05 g/dL has been shown to be an effective strategy that has reduced alcohol-impaired traffic fatalities in several countries. Impaired-driving laws, including administratively suspending licenses of driving-under-the-influence (DUI) offenders and requiring alcohol ignition interlock devices be installed on the vehicles of all convicted DUI offenders, have been effective in deterring impaired driving. The most important and the most immediately effective strategy, however, is DUI enforcement, especially sobriety checkpoints and RBT.

A continuing problem with few solutions is alcohol involvement in pedestrian and bicyclist crash fatalities. In the US, about 34% of pedestrians killed in crashes have BACs ≥ .08 g/dL while in the UK, 48% of pedestrian deaths involve alcohol. That proportion is even higher in South Africa, where 61% of pedestrian deaths involve alcohol [165].

A system being developed called the Driver Alcohol Detection System for Safety (DADSS) in the US and future fully autonomous vehicles worldwide promise to be the ultimate solution to eliminating alcohol-impaired driving.

Alcohol Impairment and Blood Alcohol Concentration

Laboratory and test-track research has shown that a vast majority of drivers, even experienced drinkers who typically reach BACs of .15 g/dL or greater, are impaired in performing critical driving tasks at .05 g/dL BAC and higher. There are significant decrements in performance in areas such as braking, steering, lane changing, judgment, and divided attention at .05 g/dL BAC. Some studies report that performance decrements in some of these tasks are as high as 30%–50% at .05 g/dL BAC [58,68,69,87,92,132,133].

Relative Risk of Being Involved in a Crash by Blood Alcohol Concentration

The risk of being involved in a crash increases with increasing BAC level in general, but rises very rapidly after a driver reaches or exceeds .05 g/dL BAC [14,15,27]. Other studies indicate that the relative risk of being killed in a single-vehicle crash for drivers with BACs of .05 g/dL to .079 g/dL is at least 7 times that of drivers at .00 g/dL BAC (no alcohol), and could be as much as 21 times that of non-drinking drivers depending on the age of the driver [193,213]. These risks are significant. See **Figure 1** from Blomberg et al. [14].
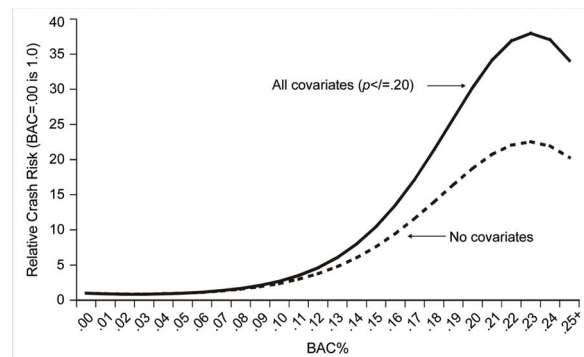

Figure 1. Relative risk of a crash by BAC with covariates and without covariates. Figure is reproduced with permission from Ref. [14].

Impaired Drivers on the Roads in the US

Since 1973, five national surveys of US drivers have estimated the prevalence of drinking and driving, showing how this prevalence has changed over time (1973, 1986, 1996, 2007, 2013–2014). In the first three National Roadside Surveys (NRS) (1973, 1986, 1996), breath alcohol tests were given to drivers on the roads on weekend nights. In 2007 and in 2013–2014, the fourth and fifth NRS studies changed their methodology to become a national field study to estimate the prevalence of alcohol-, drug-, and alcohol-plus-drug-involved driving among daytime drivers on Friday as well as nighttime weekend drivers [10,105,148]. These two NRSs involved randomly stopping drivers at 300 locations across the continental US. The locations were selected through a stratified random-sampling procedure. Researchers collected the data during a 2-hour Friday daytime session (either 9:30 am to 11:30 am or 1:30 pm to 3:30 pm) at 60 locations and during four 2-hour nighttime periods (10 pm to midnight and 1 am to 3 am on Friday and Saturday nights) at 240 locations, for the total of 300 locations.

The data collected in these surveys included both self-reported use of alcohol and other drugs and biological measures such as BAC levels. The goal was to obtain at least 7,500 oral fluid samples for analysis. Oral fluid and blood samples were subjected to laboratory screening and

liquid or gas chromatography-mass spectrometry confirmation respectively for alcohol and six classes of drugs, allowing researchers to estimate a national prevalence of alcohol and other drugs used by drivers. All drivers' responses were completely voluntary and anonymous. **Figure 2** shows the percentages of drivers who had been drinking alcohol as estimated in these surveys (*see* [24] for the international perspective).
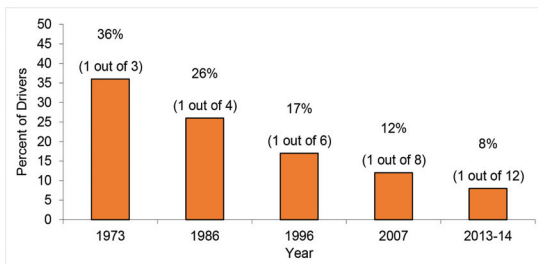

Figure 2. Percent of drivers on US roads with positive BAC levels (BAC ≥.01) (weekend evenings). Figure is constructed based on data appearing in Ref. [10,105,148].

Impaired Drivers in Fatal Crashes in the US

Since 1982, the US has been tracking the BACs of drivers fatally injured in traffic crashes. Trends in BACs in fatally injured drivers were examined and reported under the US Fatality Analysis Reporting System (FARS) from 1982 to 2016 [140]. In 2016, BAC levels could be determined for 61% of driver fatalities. When BAC data were unavailable, the estimated BAC was statistically imputed using crash, driver, and other characteristics to obtain more complete and accurate alcohol data [167]. In 2016, 30% of fatally injured drivers had impairing BACs (≥.05 g/dL); 28% were at or above the illegal BAC limit in the US (BAC ≥.08g/dL); and 12% had very high BACs (≥.20g/dL). These percentages are a vast improvement over 1982 when the percentages were, respectively, 52% (≥.05g/dL), 49% (≥.08g/dL), and 22% (≥.20g/dL). How-

ever, most of the reductions occurred before 1997, and the percentages of fatally injured drivers with BACs in the above ranges have changed little since then. While the number of drivers killed in crashes decreased 4% between 1997 and 2016, the proportion with impairing BAC levels (≥.05 g/dL) has ranged from 36% in 2008 and 2009 to 30% in 2016 (*see* **Figure 3**). (Drugs other than alcohol are not consistently tested for in FARS so they are not included in the analyses presented below).

Arrests for Driving Under the Influence in the US

In 1989 there were an estimated 1,940,000 arrests for DUI in the US [41]. **Figure 4** shows that arrests had declined by 49%, to an estimated 990,000, by 2017 [41]. As demonstrated in Figure 3, this decline was not due to a decrease in the prevalence of impaired driving in fatal crashes. So a research dilemma is to determine why the percent of impaired drivers in roadside surveys decreased significantly, and DUI arrests decreased significantly, yet the percent of drivers in fatal crashes who are alcohol-impaired has not decreased since 1997.

While DUI arrest rates in a community have been shown to correlate with impaired driving on the roads and with crashes in that community [56], the actual risk of arrest for DUI in the US is quite small. Estimates have varied from 1 in 2,000 impaired drivers, based on an analysis of average annual officer arrest rates (2 per year per officer) [17], to about 1 in 88 impaired drivers, based on responses to a national telephone survey and FBI crime statistics [212]. The most carefully developed risk estimates were those reported by Beitel, Sharp, and Glauz [9] and by Hause, Voas, and Chavez [74], based on studies in which field researchers rode with police. They found a probability of arrest for 6 in 1,000 drivers with BACs of .10 or higher. A more recent study estimated that only
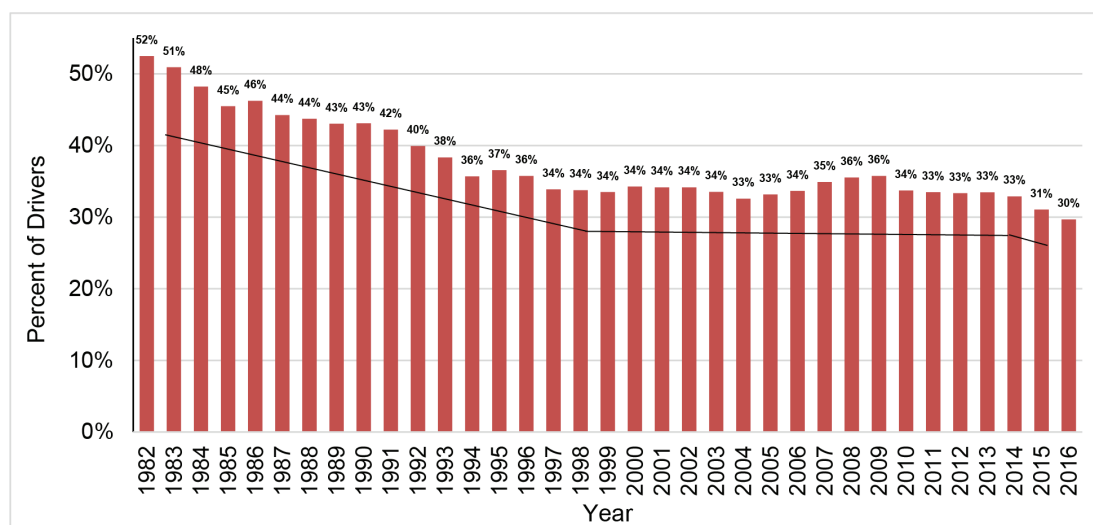

Figure 3. Proportion of all f*atally i*njured drivers estimated to have been impaired (BAC ≥.05), 1982–2016 (–42%). Figure is constructed based on data appearing in Ref. [140].
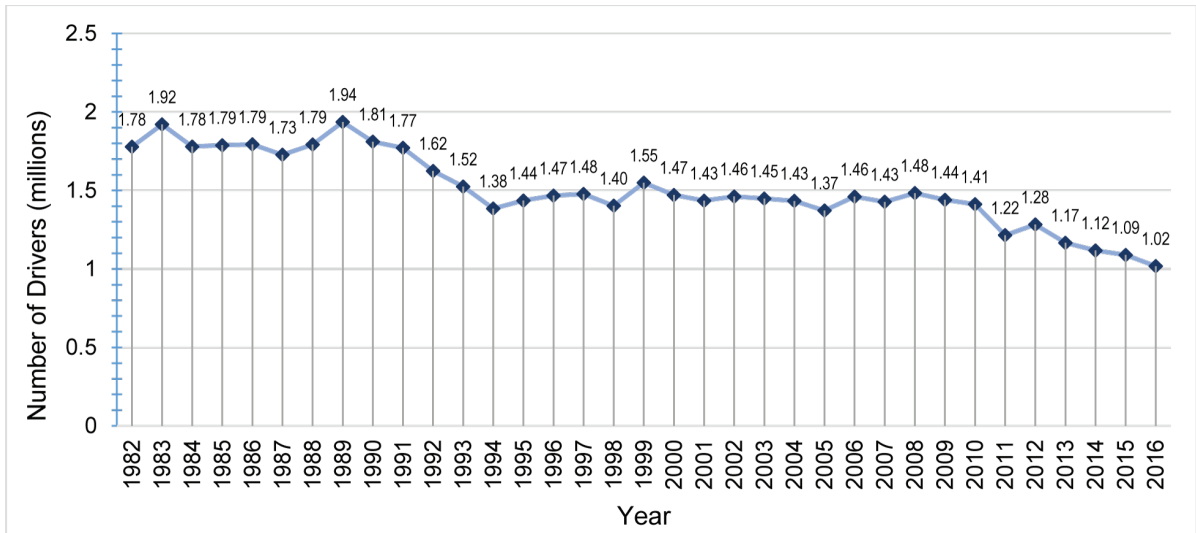
Figure 4. DUI arrests in the US: 1982–2016. Figure is constructed based on data appearing in Ref. [41].

about 1 in 1,000 drivers on the roads with illegal BACs (>.08 g/dL) is ever arrested for DUI [215]. The US public is generally not aware of these low probabilities [153].

The next sections of the article present evidence-based countermeasures that have been associated with valid measures of reduction in alcohol-impaired driving. These countermeasures have proven to be effective or to have strong potential to reduce impaired driving in the future.

I. PRIMARY PREVENTION: REDUCING HIGH-RISK DRINKING AND HIGH-RISK DRIVING

A. Alcohol-Control Policies: Limiting Alcohol Availability

1. Minimum Legal Drinking Age Laws

Minimum legal drinking age (MLDA) laws were established in the US after the repeal of Prohibition in 1933. Many states set the MLDA at 21 during that time. When the voting age was lowered from 21 to 18 in 1971, many states lowered their legal drinking age to 18 or 19. Studies in the 1970s and 1980s showed significant increases in alcohol-related crashes involving youth aged 18 to 20 in states that lowered their drinking age [22,28,59,199,204]. Later, several studies showed that raising the drinking age lowered traffic crashes and crash fatalities [82,195,205]. Consequently, the US Congress adopted the National Uniform Drinking Age 21 Act, which provided a substantial financial incentive for states to adopt a MLDA of 21, and President Reagan signed the bill into law in 1984. Since 1988, the MLDA has applied to age 21 for both the purchase and possession of alcohol in all 50 states and the District of Columbia (DC).

Between 1982 and 1998, the population-adjusted fatal crash rate involving drinking drivers aged 20 and younger in the US decreased 59% [75]. MLDA-21 laws have been shown to be independently associated with part of this

decline [144,162,172,191,198]. The National Highway Traffic Safety Administration (NHTSA) has estimated that MLDA laws save approximately 900 lives a year in traffic fatalities alone [5,98,137,208]. Other studies have shown that homicides [94,145], suicides [11], and unintentional injuries [94] by 18- to 20-year-olds have also fallen as the MLDA has risen to 21.

Numerous studies [101,144,192,194,198], including a comprehensive review of literature from 1960 to 1999 by Wagenaar and Toomey [198], have uniformly shown that increasing the minimum drinking age has significantly decreased self-reported drinking by young people, the number of fatal traffic crashes, and the number of arrests for DUI involving youths aged 20 and younger. Shults et al. [162] conducted a metaanalysis of 33 studies of the MLDA and reported that it resulted in changes of 10% to 16% in fatal crashes: increasing fatal crashes if the MLDA was lowered, and decreasing fatal crashes if it was raised. Kypri et al. [103] found that when New Zealand lowered its drinking age from 20 to 18, crash injuries among 15- to 19-year-olds increased. While many youth under age 21 still drink alcohol, raising the legal drinking age makes it more difficult to obtain alcohol and to drink and drive. The MLDA-21 law has been considered one of the most important public health policies adopted in the US [162].

2. Law Components Associated with MLDA

Legal research involving the use of the Alcohol Policy Information System (APIS) [142] has indicated that there are at least 20 MLDA-21 laws that have been adopted at the state level in the US [50]. Table 1 contains a brief summary of those 20 laws; in parentheses is the number of states (including DC) that have currently adopted each law.

In a study assessing all 20 MLDA laws, nine were found to be associated with significant decreases in fatal crash ratios of underage drinking drivers [50]: penalties

for possession of alcohol (–7.7%), penalties for purchase of alcohol (–4.2%), license loss with alcohol use (–7.9%), .02 BAC limit for underage drivers (–2.9%), bartenders required to be over 21 (–4.1%), institution of a state responsible-beverage-service program (–3.8%), fake-identification-detection support provisions for retailers (–11.9%), dram-shop liability for underage-drinking-related crashes (–2.5%), and social-host civil liability for underage-drinking–related crashes (–1.7%). The nine effective MLDA-21 laws were estimated to save approximately 1,135 lives annually, yet only five states have enacted all nine. If all states adopted these nine laws, an additional 210 lives could be saved in the US every year.

3. Responsible-Beverage-Service Training and Enforcement

In a systematic review of interventions designed to reduce alcohol use and related harms in drinking environments, Jones et al. [93] included seven studies that evaluated server-training interventions to increase responsible-beverage-service (RBS) practices. Three of the seven studies specifically examined the impact of server training on RBS-intervention practices by servers. One found no impact, and the other two found some increases in server intervention. Both studies, however, indicated a low frequency of intervention among the trained servers. Evidence on the effects of server-intervention programs

Table 1. US minimum legal drinking age 21 (MLDA-21) law components and descriptions

MLDA-21 law components	Description
Core Laws That Apply to Youths	
1 Possession	Illegal for youths under age 21 to possess alcohol (50 states + DC)
2 Purchase	Illegal for youths under age 21 to purchase or attempt to purchase alcohol (47 states + DC)
Expanded Laws That Apply to Youths	
3 Consumption	Illegal for youths under age 21 to consume alcohol (34 states + DC)
4 Internal possession	Evidence of possession and consumption via a BAC test (9 states).
5 Use and lose	Alcohol citation for a youth under age 21 results in driver's license suspension (39 states + DC)
6 Use of fake identification	Fake ID minor — Illegal for a youth under age 21 to use a fake identification to purchase alcohol (50 states + DC)
Apply to Youth Driving	
7 Zero tolerance	ZT — Illegal for drivers under age 21 to have any alcohol in their system when driving (50 states + DC)
8 Graduated driver licensing with night restrictions	GDL — Youths with intermediate or provisional license prohibited from driving without an adult in the vehicle past a certain hour at night (50 states + DC)
Apply to Providers	
9 Furnishing or selling	Illegal to furnish or sell alcohol to youths under age 21 (50 states + DC)
10 Age of on-premise servers	Minimum age 21 set for selling/serving alcohol (13 states)
11 Age of on-premise bartenders	Minimum age 21 for bartenders (23 states + DC)
12 Age of off-premise sellers	Minimum age 21 set for selling/serving alcohol (23 states)
13 Keg registration	Identification number for beer keg and purchaser required (30 states + DC)
14 Responsible beverage service training	RBS — Responsible beverage training mandatory or voluntary (37 states + DC)
15 Retailer support provisions for fake identification	Fake ID retailer — Provisions to assist retailers in avoiding sales to youths under age 21 (45 states)
16 Social host prohibition	SHP — Prohibits social hosting of underage drinking parties (28 states).
17 Dram shop liability	Action against commercial provider of alcohol (44 states + DC).
18 Social host civil liability	Action against non-commercial (private) provider of alcohol (33 states).
Apply to Manufacturers or Suppliers of Fake Identification	
19 Transfer/production of fake identification	Fake ID supplier — Prohibits manufacturing and/or supplying fake identification to youths for the purposes of buying alcohol (24 states)
Apply to States Concerning Control of Alcohol Distribution	
20 State control of alcohol sales	State control — A state-run retail distribution system of alcoholic beverages, i.e., beer, wine spirits (11 states)

on patrons' alcohol consumption has also been mixed. One study of statewide-mandated server training [84] showed that it had a statistically significant effect on single-vehicle nighttime crashes. Another study [71] found that an intervention designed to reduce aggression among bar patrons (better lighting, visible presence of bouncers) had a modest impact on severe and moderate patron aggression (reduction in verbal arguments and physical fights).

Other research on RBS programs has shown that RBS practices can be a valuable tool in lowering rates of high-risk alcohol consumption and impaired driving. For example, Johnsson and Berglund [91] found that server-training programs can help reduce the level of intoxication of bar patrons. In their study, the average BACs of patrons of bars given a server-training program were reduced more than the BACs of patrons at the control bars at a one-month followup. In a study by Toomey et al. [173], the owners and managers of five bars in Minnesota received information on risk level, policies to prevent illegal sales, legal issues, and communication on alcohol-serving issues. The result of underage and pseudo-intoxicated (actors pretending to be drunk) purchase attempts conducted before and after the intervention showed that underage sales decreased by 11.5% and pseudo-intoxicated sales fell by 46% compared to the control bars.

Two communities in the US — Rochester, NY, and Cleveland, OH — participated in a demonstration and evaluation of a set of bar-related interventions [45]. The intervention programs applied RBS training, targeted enforcement, and corrective actions by law enforcement to a random sample of 10 identified problem bars in each community, and results were compared to those for 10 matched problem bars without interventions. In Rochester, the percentage of intervention-bar patrons who were intoxicated decreased from 44% before the intervention to 27% after the intervention, which was statistically significant relative to the comparison bars. The average BAC of patrons in the intervention bars decreased from .097 g/dL (over the .08 g/dL limit for driving) to .059 g/dL pre- to postintervention relative to the comparison bar patrons. In Cleveland, the percentage of pseudo-intoxicated patrons (actors pretending to be intoxicated) who were denied service in the intervention bars increased from 6% to 29%. This was significant relative to the comparison bars. It appears that when bar managers and owners are aware of the program and its enforcement and when servers are properly trained in RBS, fewer patrons may become intoxicated and greater efforts may be made to deny service to obviously intoxicated patrons. Given that about a third to half of all arrested impaired drivers had their last drink at a licensed establishment (bar, tavern, or restaurant) [2,35,143], widespread implementation of this strategy has the potential to help reduce impaired driving.

B. Citizen-Activist Organizations (e.g., Mothers Against Drunk Driving) in the US

In the early 1980s, the public's attitude toward drinking and driving in the US was substantially transformed by the victim-activist movement, marked by the founding and growth of Mothers Against Drunk Driving (MADD). Media coverage of drinking and driving increased [25,134]. Most observers credit victim-activist groups, particularly MADD, for this sudden increase in press coverage [122]. The sanctions for impaired driving also increased. Merki and Lingg [129] concluded that MADD has been a major force behind the adoption by states and communities of eight effective impaired-driving strategies. McCarthy and Ziliak [123] found that the presence of a MADD chapter significantly reduced the number of DUI crashes resulting in injuries.

Fell and Voas [53] estimated that 300,000 lives were saved between 1982 and 2004 due to the reduction in traffic fatalities involving impaired driving. The reduction in alcohol-related fatalities following the emergence of MADD supports the hypothesis that the group had an important effect on impaired driving in the 1980s. The continuation of substantial reductions into the early 1990s, when MADD emerged as the primary victim-activist organization, suggests that it had the primary influence on the observed reduction. Marshall and Oleson [118] described the beneficial effects of MADD's victim services, and McCarthy and Wolfson [121] concluded that an affiliation with MADD appeared to energize local leaders in countering drunk driving. Compton [26] found an effect of the adjudication of DUI offenders due to MADD's court-monitoring program.

MADD is still an active organization working to reduce impaired driving in the US. But progress has stagnated due to many competing issues that decrease attention to alcohol-impaired driving — by the public and by law enforcement (e.g., distracted, drowsy, and drugged driving).

C. Reducing High-Risk Driving by the Young

1. Graduated Driver-Licensing Laws

Research has shown that the first few months of licensure for young novice drivers entail the highest crash risk [120,124,156,203]. To address this issue, all US states and numerous other countries (e.g., Australia, New Zealand, the UK, South Africa, Canada) have adopted graduated driver-licensing (GDL) laws that require a staged progression to full license privileges.

GDL laws generally require three-staged licensing for novice drivers: (a) a learner's permit period — practice driving with a licensed driver aged 21 or older; (b) an intermediate or provisional stage — drive solo only under certain conditions (e.g., restricts late-night driving

and limits teen passengers); and (c) a full license with no restrictions (minimum age of 18 in some states and most other countries). The young driver must meet certain requirements to "graduate" to each stage. Evaluations of state programs in Florida [175], North Carolina [61,62], and Michigan [160,161] showed reductions in crashes involving 16- and 17-year-olds that ranged up to 26%. Chen et al. [23] found that GDL programs appeared to be associated with an 11% reduction in fatal crashes involving 16-year-olds in the states that had implemented them. Several national studies of GDL systems in the US have indicated they help reduce the crash rates of young novice drivers aged 15 to 17 [31,125,177].

2. Nighttime Driving and Passenger Restrictions for Young Drivers

Preusser et al. [147] explored the influence of nighttime curfew policies by comparing crash rates for young teenagers (aged 15, 16, or 17, depending on the state) in states with and without curfew laws. These researchers estimated reductions in the crash involvement of 16-year-old drivers during curfew hours ranging from 25% to 69% and concluded that the laws were beneficial relative to their costs. Consequently, nighttime and passenger restrictions were incorporated into all GDL laws.

The nighttime and passenger restrictions under the GDL laws have been evaluated for their effectiveness [52]. Nighttime restrictions reduced 16- and 17-year-old driver involvements in nighttime fatal crashes by an estimated 10% and 16- and 17-year-old drinking drivers in nighttime fatal crashes by 13%. Passenger restrictions were found to reduce 16- and 17-year-old driver involvements in fatal crashes with teen passengers by an estimated 9%. These results confirm the effectiveness of these provisions in GDL systems.

In a study of GDL laws by Masten et al. [119], substantial reductions (down 26%) in fatal crashes for 16-year-old drivers were found to be associated with the adoption of strong GDL laws, but for 18-year-olds fatal crashes increased in those same states (up 12%). The authors suggested that strong GDL laws might have delayed licensure of many youth until they were aged 18 to avoid all the GDL provisions and requirements. An analysis by Fell et al. [47] indicated similar results. Estimates based on the statistically significant (p <.05) findings for each age group found that for 16-year-olds, 1,945 lives were saved by GDL-related reductions in fatal crashes, but these were offset by increases in fatal crashes for older teens. For the strong GDL laws, there was a net increase in fatalities of 377 due to the increase in fatal crashes by drivers aged 18, with an additional increase of 855 fatalities if the 19-year-old increase is included. Strong GDL laws resulted in 2,347 lives saved due to the reduction of drivers aged 16 in fatal crashes but were associated with

an increase of 2,724 fatalities from fatal crash involvements of drivers aged 18.

The outcome of these two studies indicate once more that GDL laws save the lives of the population they target: novice drivers aged 15 to 17 and especially drinking novice drivers. This favorable impact is even larger for the better GDL programs (i.e., the enacted GDL is "good"). These results also indicate that the lives of some drivers aged 15 to 17 saved by GDL laws are offset by the associated increases in fatal crashes by drivers aged 18 and 19. The reasons for the conflict in GDL benefits are still unclear. Factors include: (a) drivers aged 18 and 19 skipping the GDL phases and beginning to drive at a later age, reducing their driving experience; (b) drivers aged 18 and 19 exhibiting more risk-taking behaviors (e.g., impaired driving, lack of safety belt use, distracted driving) than younger drivers; (c) drivers aged 18 and 19 having increased exposure to risk for a fatal crash (e.g., more late-night driving; more driving on high-speed roads); and/or (d) drivers aged 18 and 19 who have gone through the two phases of GDL lacking driving experience under risky conditions because of all the restrictions in the GDL laws. Whatever the reasons, this finding suggests that perhaps GDL laws should be applied to protect novice drivers older than ages 16 and 17, for example up to age 21 (although this might just postpone the increase in crashes to drivers over age 21). Further research to clarify this dilemma is needed.

II. SECONDARY PREVENTION: REDUCING DRINKING AND DRIVING

A. Evidence-Based Legislation

1. Illegal BAC Limits for Driving

The BAC levels that are used by states to define impaired driving for enforcement purposes are based on case-controlled relative-risk studies such as Borkenstein et al.'s [17] and Blomberg et al.'s [14,15,193,213]. Initially set at .15 g/dL BAC in the 1950s, state BAC limits in the US were generally lowered to .10 g/dL BAC by the 1980s. The strong evidence that BACs as low as .05 g/dL increased crash risk motivated several states to lower their limit to .08 g/dL in the 1990s. By 2000, the US Congress passed legislation encouraging all states to adopt .08 g/dL BAC laws by threatening to withhold a portion of a state's federal highway funds for noncompliance. This movement stimulated many research studies of the effectiveness of lowering the BAC limit from .10 g/dL to .08 g/dL. Most of these studies found sizable decreases in alcohol-related crashes associated with the .08 g/dL BAC limit. Between 1991 and 2000, nine evaluations of .08 g/dL laws involving 11 states were conducted in the US [3,63,78,80,90,149, 150,190,192]. A metaanalysis by Schults et al. [162] of

25 studies on the enactment of the .08 law found that the median crash reduction among the studies they reviewed was 7%. A more recent panel study of the overall effects of the .08 BAC law in all 50 states and DC in the US found a 10.4% reduction in the drinking-driver fatal crash rate associated with the lowered BAC [157].

Fell and Voas [55] conducted a general review of studies of the effect of lowering the BAC limit in foreign countries and the US, and concluded that further lowering the BAC limit to .05 g/dL would be likely to reduce alcohol-related crashes. In 1988, the illegal BAC limit was lowered from .08 g/dL to .05 g/dL in Austria. A study of the law found that there was an overall 9.4% decrease in alcohol-related crashes relative to the total number of crashes [7]. However, they noted that intense media and enforcement campaigns also occurred around the time that the limit was lowered, making it nearly impossible to attribute the reductions to any one of these factors, at least in the short term. Bartl and Esberger [7] concluded that "lowering the legal BAC limit from .08 g/dL to .05 g/dL in combination with intensive police enforcement and reporting in the media leads to a positive short-term effect." This provided support for the view that a limit of .05 g/dL BAC or less, as part of a comprehensive approach to fighting impaired driving, can have beneficial effects.

Homel [85] found that lowering the BAC limit from .08 g/dL to .05 g/dL in New South Wales, Australia, significantly reduced fatal crashes on Saturdays by 13%. Henstridge et al. [77] conducted a rigorous time-series analysis of RBT and .05 g/dL BAC laws in Australia, controlling for many factors including seasonal effects, weather, economic trends, road use, alcohol consumption, and day of the week. Although the primary focus of the Australian study was the impact of RBT, the findings on the effect of .05 g/dL BAC laws were also significant. The study statistically accounted for the effect of other alcohol countermeasures to determine the specific values of the declines that were attributable directly to either RBT or the lower .05 g/dL BAC limit. The study analyzed traffic data for periods ranging from 13 to 17 years and found Australian states that lowered their BAC limits from .08 g/dL to .05 g/dL experienced meaningful declines in alcohol-related crash measures. For example, after Queensland, Australia, reduced its per se (i.e., no other evidence needed; just exceeding the BAC limit is illegal) BAC limit to .05 g/dL in 1982, it experienced an 18% reduction in fatal collisions and a 14% reduction in serious collisions. These results were not confounded by the effects of RBT, as it was not introduced until 8 years later. Similarly, the .05 g/dL BAC limit in New South Wales was estimated to have reduced serious collisions by 7%, fatal collisions by 8%, and single-vehicle nighttime collisions by 11%.

Smith [163] specifically evaluated the effects of lowering the BAC limit in Queensland from .08 g/dL to .05 g/dL BAC. A proxy measure of changes in nighttime crashes as compared to daytime crashes was used. There was a significant 8.2% reduction in nighttime serious injury crashes (requiring hospitalization) and a 5.5% reduction in nighttime property-damage crashes associated with the .05 g/dL BAC limit in the first year. Smith partially attributes the crash reductions in the second and third years after the adoption of .05 g/dL BAC to increased enforcement. Smith concludes that when lowering the BAC limit stimulates increased enforcement, it should be considered a benefit rather than a drawback of the law.

The evidence for lowering the BAC limit for driving, especially to .05 g/dL, is very strong. It apparently sends a message to would-be drinking drivers that the government is getting tougher on impaired driving and serves as a general deterrent to drinking and driving.

2. Zero-Tolerance Laws for Novice Drivers

By 1988, all states in the US had enacted MLDA laws making it illegal for those younger than 21 to purchase or possess alcohol. This provided a basis for implementing a zero-BAC limit for drivers aged 20 and younger. In 1995, the US Congress passed a law creating a financial penalty (a reduction in their highway construction funds) for states that did not adopt zero-tolerance laws for drivers younger than 21. By 1998, all states and DC had passed laws making it illegal for any driver younger than 21 to have a positive BAC (generally defined as a BAC of .02 g/dL or greater). These zero-tolerance laws for youth have proven effective in reducing fatal crashes involving underage drinking drivers [13,44,79,81,191,216]. Shults et al. [162] conducted a metaanalysis of the studies of zero-tolerance laws and found reductions of 9% to 24% in fatal crashes. Zero-tolerance laws for young drivers are now being adopted in several countries.

3. Administrative License Revocation

Administrative license revocation (ALR) or suspension (ALS) is the administrative revocation or suspension of the driver's license of a driving-while-intoxicated (DWI) or DUI offender at the time of arrest [104]. ALS differs from traditional judicial license actions in several ways. First, anyone arrested for DUI in the US in a state with an ALS law is immediately subject to ALS. Usually, the arresting officer confiscates the license and issues a notice of ALS. Often, the notice of ALS may serve as a temporary license for a period (e.g., 10–30 days) during which the driver may request an administrative hearing for license reinstatement. Regardless of the outcome of such a hearing, the arrestee is still subject to a separate criminal charge

that may lead to additional penalties, including judicial license actions [206].

At the end of the suspension period, some states reissue the license back to the driver, often charging a license-reinstatement fee and requiring verification of insurance. Other states require a complete driver's license reexamination, including a reinstatement fee, before driving privileges are restored. Some states suspend the license but issue a hardship license while the suspension remains in effect [138].

ALR or ALS laws have been shown in a nationwide study to reduce fatal crashes involving drinking drivers by 13% to 19% [192]. Wagenaar and Maldonado-Molina [196] found that ALR laws have statistically significant and substantially important effects in reducing impaired-driving fatal crashes pooled across states; the 5% reduction in crashes represented at least 800 lives saved per year. Other earlier studies [99,152,162,192,199,202,214] have shown similar effects for ALR/ALS laws. Kenkel [96], in an econometric analysis, evaluated ALR laws along with mandatory jail sentencing, preliminary breath testing, sobriety checkpoints, and prohibition of plea bargaining, and concluded that stricter laws could decrease drunk-driving crashes by 20%.

License suspension generally has been shown to reduce DUI offender recidivism when suspended offenders are compared with offenders that avoid suspension [73,107,127]. There is also strong evidence that ALR laws have had a general deterrent effect on impaired-driving fatal crashes, as summarized by Jones and Lacey [95]. Studies in other countries have confirmed the effectiveness of ALR [8,116,166]. NHTSA has sponsored studies on the effects of publicizing ALR laws [106], on the cost benefit of ALR [104], on the effects of ALR on employment [102], and on the effectiveness of allowing telephonic testimony at ALR hearings [207].

ALR laws have been challenged but ruled constitutional by the US Supreme Court [176]. The Supreme Court found that the right to due process is not violated if a driver's license is suspended prior to an administrative hearing as long as it is a swift postsuspension hearing. All other legal cases in which state appellate courts have ruled on ALR/ALS issues have held that a separate criminal trial following an ALR action does not constitute double jeopardy under federal or state laws.

A study by Fell and Scherer [48] found that ALR laws are effective and that the ALR suspension length does matter. The implementation of any ALR law (with any suspension length) was associated with a 13.1% decrease in the drinking/nondrinking driver Fatality Analysis Reporting System (FARS) ratio, but only a 1.8% decrease in the intoxicated/nonintoxicated fatal crash ratio. So the ALR law affects drinking drivers (BAC >.01 g/dL) substantially, but not intoxicated drivers (BAC >.08 g/dL). The risk of a fatal crash increases at each increase in the BAC level [193], so it appears that ALR laws send a message to not drink and drive (BAC = .01–.07 g/dL) or you will lose your license, but apparently does not reach drivers who get intoxicated and then drive (BAC ≥.08 g/dL). According to the fatal-crash data, more than half of intoxicated drivers (BAC ≥.08 g/dL) in fatal crashes have very high BACs (BAC ≥.15 g/dL). These are binge drinkers and/or abusive drinkers. Perhaps moderate drinkers (BAC = .01–.07 g/dL), the majority of drinking drivers on US roads [10], fear the loss of their license more than binge drinkers (BAC ≥.08 g/dL) do, or have more ability to moderate their alcohol-related behaviors in response to perceived risks.

Regarding ALR suspension length, even a short suspension period of 1–30 days has a significant effect on the drinking-driver ratio (p <.001) compared to having no ALR law. However, suspension periods of 31–90 days are no better than periods of 1–30 days. States with ALR suspension periods of 91–180 days had significantly larger (p <.001) reductions in drinking drivers than states with suspension periods of 1–90 days, as did the three states with suspension periods greater than 180 days compared to states with suspension lengths of 1–180 days (p = .013).

4. Primary Enforcement Safety-Belt Laws

NHTSA estimates that safety belts, when worn in a passenger car involved in a serious crash, are 45% effective in preventing fatalities [100]. Klein and Walz [100] also tracked vehicle safety belt use in the FARS from 1982 through 1995 and found non-use to be positively correlated with BAC levels for every year. In 1995, 75% of drivers at .10 g/dL BAC did not use safety belts compared to 34% of the drivers at zero BACs. There are two types of state laws regarding safety belt use: secondary laws, which allow officers to cite unbelted drivers only if they are stopped for some other traffic offense, and primary laws, which permit stopping the vehicle of an unbelted user.

Lange and Voas [108] found that when California moved from a secondary to a primary law, belt wearing increased from 70% to 90% among nondrinking drivers. In contrast, the usage rate among drivers with BACs of .10 or higher increased from 50% to 90%. Aside from their direct effect in reducing the severity of injuries, primary safety-belt laws may be particularly effective in deterring impaired drivers because they allow the officer to stop the car, leading to the detection of drinking. Further evidence for the potential effectiveness of primary safety-belt laws

in reducing impaired-driving crashes was provided by Voas, Fell, Tippetts, Blackman, and Nichols [184]. In a study of five states that passed primary safety-belt laws, four experienced significant declines in alcohol-related fatal crashes relative to non–alcohol-related fatal crashes.

B. Law Enforcement Strategies

1. Sobriety Checkpoints and Random Breath Testing

The highly successful random breath-test (RBT) enforcement procedure used in Australia, Sweden, and other countries allows officers to stop any vehicle on the road at random and to require the driver to take a breath test. Operators with BACs higher than the legal limit are transported to the police station for an evidential test. A study in 1997 found that RBT was twice as effective as "selective" checkpoints similar to those conducted in the US [77]. An earlier study in 1990 found that in Queensland, Australia, RBT resulted in a 35% reduction in fatal crashes, compared with 15% for checkpoints [159]. The researchers estimated that every increase of 1,000 in the daily RBT testing rate corresponded to a decline of 6% in all serious crashes and 19% in single-vehicle nighttime crashes. Moreover, analyses revealed a measurable continuing deterrent effect of RBT on the motorist population after the program had been in place for 10 years. A study in 1988 showed that the deterrent influence of RBT also provided heavy drinkers with a legitimate excuse to drink less when drinking with friends [86]. A review of the effectiveness of sobriety checkpoints in Thailand was conducted in 2011 and concluded that barriers to successful enforcement needed to be overcome for the strategy to be effective [34]. In a follow-up study of the cost-effectiveness of sobriety checkpoints in Thailand [33], the authors concluded that checkpoints need to be conducted with greater intensity to complement the investment in publicity campaigns.

In contrast, vehicles in the US can only be stopped at random at specially designated "checkpoints" and drivers cannot be required to take a breath test. Rather, the officer must conduct an interview to determine whether the driver is impaired, and if there is evidence of impairment, the officer must require the driver to perform a set of field sobriety tests to establish impairment before transporting the offender to the police station. Studies of the US sobriety-checkpoint procedure found that checkpoints are associated with significant decreases in alcohol-related crashes [39,106,110,111,178,188,200]. Two related metaanalyses of 15 US checkpoint programs occurring between 1985 and 1999 found that the median reduction in crashes associated with checkpoints was 20% [37,162]. A cost-benefit study of sobriety checkpoints indicated that, for every $1 invested in the checkpoint strategy, the community conducting the checkpoint saved $6 [130].

C. Impaired-Driving Enforcement Technology

1. Passive Alcohol Sensors

In the US, police departments have resisted implementing checkpoints, partly because few DUI arrests are made in checkpoint operations [46]. An important factor limiting arrests is the fact that officers cannot test every driver stopped, as they do in Australia, but must first determine that the individual has been drinking and may be impaired. A device designed to aid the officer in detecting drinking is the Passive Alcohol Sensor, a standard police flashlight with a built-in passive alcohol sensor (*see* **Figure 5**). It draws in a mix of expired and environmental air from in front of a person's face and is not considered a search prohibited by the Fourth Amendment. These sensors can provide a good estimate of the driver's BAC [40,189]. The PAS is particularly effective when observation time is short, as it is at checkpoints.

However, efforts to persuade officers to make greater use of passive sensors have generally failed [43] (e.g., PAS devices are too expensive; officers can detect alcohol as well as the PAS, etc.). A series of studies has demonstrated that when officers use passive sensors at a checkpoint, more drinking drivers are detected and the arrest rate increases by approximately 50% [57,109,113,114]. Aside from its effectiveness in increasing the detection of drinking drivers, the most important effect of the PAS on impaired driving may be its potential to increase the perceived risk of being apprehended for DUI if driving after drinking. If police use of the PAS is well publicized, it should increase general deterrence to impaired driving. Heavy drinkers who count on their increased tolerance to alcohol to avoid detection [151,152] might be deterred by the police's ability to detect drinking in an otherwise sober-appearing driver. Further, making underage drivers aware that even very small amounts of alcohol in the blood can be detected should increase their concern about being cited under the zero-tolerance law. Although the PAS has been used in many enforcement programs, relatively few [186,200] have actively publicized its use. More comprehensive research on the effects of publicizing PAS use in DUI enforcement is needed.

Figure 5: A police flashlight with a built-in passive alcohol sensor (PAS V Flashlight Passive Alcohol Tester by ALCOPRO Drug & Alcohol Testing Products: Knoxville, TN). Figure is for open access; *https://www.alcopro.com/product/p-a-s-v-flashlight/* (Accessed May 21, 2019).

D. Publicizing Enforcement Programs

1. Paid Media Campaigns

Because deterrence depends on the perceived rather than the actual probability of being arrested, it is generally accepted that enforcement programs must be well publicized to be effective. General safety publicity without a related enforcement program is usually ineffective in reducing crashes. Publicizing general safety messages such as *If You Drink Don't Drive,* without an associated law or enforcement effort, has generally failed to demonstrate an effect on highway safety [202]. However, Ross [151] and Voas and Hause [185] documented crash reductions produced by publicity in advance of the application of a change such as a new law [151] or enforcement effort [185]. Sometimes, an enforcement program by itself produces enough public visibility and media attention to make the public aware of the program without a special media program [e.g., 83,178,185].

Aside from free publicity provided by the press because of an ongoing enforcement effort, three types of information campaigns help educate the public on impaired-driving laws and enforcement: (a) public service announcements (PSAs); (b) paid media campaigns; and (c) media advocacy programs. Each program has its strengths and limitations. Few media campaigns of any type have been adequately evaluated.

In relation to impaired driving, paid media campaigns have been used most frequently in national *Click It or Ticket* campaigns to increase the use of safety belts or campaigns directed at impaired driving during holidays, such as Labor Day and Christmas, when many local police departments receive funding to implement special enforcement efforts [171]. Mass media efforts alone are insufficient, however. Friend and Levy [65] conducted a comprehensive review of mass media campaigns on tobacco. Results suggested that well-funded and implemented mass media campaigns targeted at smokers, with a comprehensive tobacco-control program, were associated with reduced smoking rates among both adults and youths. Similar strong effects of paid media on impaired driving remain to be demonstrated.

III. TERTIARY PREVENTION: PREVENTING REPEATED INFRACTIONS BY IMPAIRED-DRIVING OFFENDERS

A. Sanctions for Impaired-Driving Offenders

1. Driving While Intoxicated (DWI)/DUI Drug Courts

Based on the effectiveness of Drug Court models, DUI Courts are gradually increasing. Modeled after Drug Courts, these DUI Courts are designed to provide constant supervision to offenders by judges and other court officials, who closely administer and monitor compliance with court-ordered sanctions coupled with treatment. DUI Courts generally involve frequent interaction of the offender with the DUI Court judge, intensive supervision by probation officers, intensive treatment, random alcohol and other drug testing, community service, lifestyle changes, positive reinforcement for successful performance in the program, and jail time for noncompliance. In jurisdictions that have DUI Courts, nonviolent offenders who have had two or more prior DUI convictions typically are assigned to DUI Court.

DUI Courts are intended to hold offenders accountable for their actions, change offenders' behavior to end recidivism, stop alcohol abuse, treat the victims of DUI offenders in a fair and just way, and protect the public [64,169]. Breckenridge et al. [20] report that these programs significantly reduces recidivism among alcoholic DUI offenders. At the end of 2003, there were approximately 70 DUI Courts and 1,200 Drug Courts operating in the US. By the end of 2007, there were an estimated 400 DUI Courts and 2,000 Drug Courts overall [88]. A survey by NHTSA [12] found that there were 473 DUI Courts by the end of May 2015. One report on a DUI Court in New Mexico indicated that recidivism was reduced by more than 50% for offenders completing the program compared to similar offenders not assigned to the DUI Court [72]. Those results, however, were preliminary and did not include statistical tests.

Three DUI Courts in Georgia (Chatham, Clarke, Hall) were evaluated by Fell et al. [51]. Levels of recidivism for DUI Court participants (designated as the Intent to Treat Group) were compared to the recidivism rates for similar DUI offenders during the same time period but in other Georgia jurisdictions (Contemporary Group) and DUI offenders in the same three jurisdictions but before the DUI Court was established (Retrospective Group). After four years of exposure, the DUI Court participants (combined for all three courts) displayed a recidivism rate of 15%. This was compared to a recidivism rate of 24% for the Contemporary Group and 35% for the Retrospective Group.

The DUI Court participants' rates were lower by statistically significant amounts: 38% lower (p <.001) than rates for the Contemporary Group and 65% lower (p <.001) than rates for the Retrospective Group. In addition, the DUI graduates had a significantly lower recidivism rate (63.5% lower) (p <.001) than the matched contemporary offenders from other counties who completed traditional programs and 79.3% lower (p <.001) than the retrospective offenders from the same counties who would have been eligible for the DUI Court had it been operating at the time. Recidivism was also lower than the rate for the group of offenders whose licenses were terminated by DUI Court,

who had an overall rate of 26%. The 9% recidivism rate for the DUI Court Graduates was 65.1% lower (p <.001) than the rate for offenders who were terminated. Results were similar across DUI courts: the Chatham graduates had a recidivism rate of 10%, the Clarke graduates had an 11% rate, and the Hall graduates had a 7% rate. It is estimated that the DUI Courts prevented between 47 and 112 repeat DUI arrests.

DUI Courts are effective in reducing DUI recidivism and in helping offenders stop excessive drinking and return to a normal life. However, they are labor-intensive and expensive. Cost-benefit studies are needed.

2. Screening and Brief Interventions

When all three levels of prevention — primary, secondary, and tertiary — fail, many drivers become involved in crashes and wind up in hospital emergency rooms or regional trauma centers. This provides an opportunity outside the criminal justice system for the health care system to intervene with high-risk drivers. The trauma of being involved in a crash is viewed as providing a "teachable moment", when individuals may be open to undertaking a behavioral change that will reduce their risk of future crashes and injuries.

Research suggests that 30% to 50% of injured, crash-involved drivers admitted to emergency departments or trauma centers have BAC levels higher than the legal limit for driving [29,115,141,164]. Some of these offenders may receive a court-based treatment intervention because of a DUI arrest; however, many are not charged because they are taken to the hospital before police officers have an opportunity to examine them for impairment, and hospital staff rarely notify the police when they receive a high-BAC driver. When screened for alcohol-use disorders, an estimated 27% of injured patients (including those with non-crash-related injuries) admitted to emergency departments or trauma centers test positive for alcohol abuse or dependence, indicating a large number of people entering emergency rooms who are potential DUI offenders [66]. Thus, emergency rooms and trauma centers have an important opportunity to intervene with high-risk individuals who need treatment for alcohol problems — problems that may well lead to impaired-driving and alcohol-related crashes.

Evaluations indicate that brief interventions can decrease alcohol use [60,67], including excessive and binge-drinking occasions. Other alcohol-related problems and negative consequences also decreased following such interventions [128,131]. Most importantly, brief interventions effectively reduce driving-related infractions and other consequences, such as moving traffic violations [67,131], drunk-driving violations [67,131,158], motor-vehicle-crash involvement [154], crash-sustained injuries [60], and motor-vehicle fatalities [60]. Schermer et al.

[158] demonstrated that one re-arrest for DUI could be prevented for every 10 cases needing treatment who are treated. Other studies have also found that brief interventions reduce alcohol-related arrests [60,67], as well as other types of arrests [60] and general legal involvement [60].

Screening and brief interventions (SBI) in medical and public health settings have great potential to reduce excessive drinking and impaired driving. But they have yet to be implemented on a widespread basis, and further evaluation of the effectiveness and cost/benefit ratios of specific types of intervention are needed.

B. Contolling Impaired Driving by DUI Offenders

1. Alcohol Monitoring

An alternative to controlling the driving of DUI offenders is to control their drinking [180]. Judges frequently admonish offenders to remain abstinent while on probation, but unless a program exists that monitors the BAC, this action has little force other than allowing the judge to impose more severe penalties if the offender returns to court during the probation period. In the past, offender abstinence has been monitored in several ways. Some courts have implemented closely supervised and intensive-supervision programs in which probation officers make surprise visits to the homes of offenders and conduct breath tests. As noted, DUI/drug courts generally provide for intensive monitoring of abstinence. Such systems are labor-intensive and expensive for the courts. In the last couple of decades, innovative technological methods for collecting BAC data have received considerable attention.

The South Dakota 24/7 Sobriety Program is a sobriety-monitoring program aimed at repeat DUI offenders, first DUI offenders with very high BACs, and similar offenders who have had repeated convictions related to alcohol abuse. Offenders report to the Sheriff's Office twice a day (at about 7 am and 7 pm) for alcohol breath testing. If the offenders have any positive BACs or they miss a scheduled test, they go to jail for 12 to 36 h. South Dakota adopted legislation in 2007 that established the 24/7 program statewide. Depending on the circumstances, judges may also require these offenders to undergo treatment, attend victim-impact panels and/or perform a certain number of hours of community service. Some offenders (because of their working hours, the distance they must travel in rural counties, and other legitimate reasons) agree to wear a transdermal alcohol-monitoring (TAM) ankle bracelet instead of the twice-per-day breath testing. The TAM system records any alcohol use via sweat vapor every 30 min.

According to the Mountain Plains Evaluation report [112], the DUI recidivism rates after three years for 24/7 first offenders (with BACs >.17 upon arrest) was 14.3% compared to 14.8% for similar offenders not on 24/7 (no

difference). However, there was a statistically significant 74% reduction in recidivism after three years for DUI second offenders (13.7% for comparison offenders vs. 3.6% for the 24/7 offenders); a 44% reduction in recidivism for DUI third offenders (15.3% vs. 8.6%), and a 31% reduction in recidivism for DUI fourth offenders (15.5% vs. 10.7%).

The Rand Corporation conducted an independent evaluation of the South Dakota 24/7 program. According to Kilmer et al. [97], there was a 12% reduction in repeat DUI arrests and a 9% reduction in domestic violence arrests associated with the adoption of the 24/7 program.

More direct transdermal monitoring systems that are worn on the body and monitor the BAC level 24 hours a day/7 days a week are just beginning to be used by the judicial system [168]. Two devices have been studied — the Secure Continuous Remote Alcohol Monitoring (SCRAM™) ankle bracelet and the WrisTAS™, which is about the size of a large wristwatch. Introduced about 10 years ago, the SCRAM device is currently being used in 48 states and DC (excluding Hawaii and Massachusetts) in the U S. The company that produces the SCRAM bracelet reports that it works with more than 200 service providers in more than 1,800 courts and agencies around the US and that close to 250,000 offenders have been monitored to date. Thirty-four states have had more than 1,000 offenders on SCRAM and eight states have had more than 10,000 offenders using SCRAM over the years. The SCRAM incorporates a system for detecting circumvention attempts such as inserting an object between the ankle skin and the SCRAM sensor to block the sweat vapor [117].

A method for monitoring drinking that is just emerging in the US but is more widely used in Europe is to analyze the biomarkers in blood, urine, or hair that result from consumption of alcohol. Although alcohol is cleared relatively rapidly from the body, usually even after heavy drinking within 8 to 12 h, alcohol biomarkers persist in hair and in urine long after the BAC level has fallen to zero. These biomarkers provide a way to measure total consumption over an extended time span. Longer-lasting markers reflecting alcohol use, such as urinary ethylglucuronide (EtG), offer a window of detection of 36 h or more following drinking [18,76,211]. These biomarkers are currently being used in Europe to manage the drinking of offenders. Tests for such biomarkers can be required on a regular schedule with the probability that they will detect illicit drinking because they are present in the blood for an extended period following drinking. Hair EtG is being used in Germany as a relicensing criterion for participants in the driver's license restitution processes following conviction for impaired-driving. To be eligible for reinstatement, a person's hair EtG level must be below 3 pg/mg, which is known to reflect abstinence.

Monitoring alcohol consumption by DUI offenders is a key component of DUI Courts and is becoming more popular in US courts. The evidence indicates that when offenders are monitored, they tend to remain abstinent or at least refrain from excessive drinking.

IV. FUTURE DIRECTIONS

A. Future Opportunities in Primary Prevention

1. Strengthen Enforcement of MLDA Laws
There is clear evidence that MLDA laws reduce alcohol-related crashes involving underage drivers. Although there are effective measures for enforcing MLDA laws, they are not widely and consistently used. Increased enforcement is needed. Countries around the world should consider establishing age 21 as the MLDA.

2. Strengthen Enforcement of Prohibitions on Serving Drinks to Obviously Intoxicated Patrons
Bars, restaurants, and other on-the-premises alcohol outlets are a major source of impaired drivers. Laws making it illegal to serve obviously intoxicated patrons are poorly enforced. Research suggests that refusal of service can be greatly increased through increased enforcement. This opportunity to reduce the number of impaired drivers on the road should be exploited.

3. Promote Ridesharing (e.g., Uber, Lyft) and Other Alternative Transportation Options
Ride-sharing applications on smart phones have substantially changed the landscape on alternative transportation. Uber and Lyft are the two largest ride-sharing programs in the US. These programs enable passengers to hail nearby private drivers using geolocation technology. Uber and Lyft have introduced flexible pricing, automated payments, and shorter wait times than traditional taxi services. Both Uber and Lyft are in most major cities and counties in the US and are growing rapidly in other countries. While there are potential safety risks to unregulated ride-sharing services, there also appear to be several benefits: convenience, affordability, and an alternative to driving while impaired.

Three studies have been conducted on the effects of Uber on alcohol-impaired driving. The first study, sponsored by Uber and MADD, found that Uber's entry in Seattle, WA, was associated with a 10% decrease in DUI arrests [174]. In Chicago, 45.8% of Uber rides requested within 50 m of a bar, restaurant, or other alcohol outlet came during peak drinking hours (10 pm to 3 am) compared to only 28.9% at off-peak hours. In California, monthly alcohol-related crashes declined 6.5% among drivers under age 30 following the launch of Uber.

Providence College (Providence, RI) also studied the relationship between Uber, fatal crashes, and criminal arrests [32]. They examined over 150 cities and counties that introduced Uber between 2010 and 2013, and found that Uber was associated with decreases in fatal vehicular crashes and in arrests for DUI, assaults, and disorderly conduct.

A third recent study [19] conversely found that Uber had no association with the number of traffic fatalities, drunk-driving fatalities, and weekend and holiday fatalities after Uber entered the county. Brazil and Kirk [19] analyzed the FARS for several Uber counties, but it is unclear how drunk-driving fatalities were defined. It also appears that the alcohol-imputation FARS file was not used in that study, which is a standard procedure for researchers using FARS data.

While alternative transportation programs have had some effect on impaired driving, ride-sharing programs such as Uber and Lyft hold promise to have substantial effects as the market penetration increases. However, very few of the alternative transportation studies are truly scientific. A properly designed, scientifically rigorous, controlled study that would be both approved by experts and understood by the public is therefore required.

B. Future Opportunities in Secondary Prevention

1. Increase Use of Low-Staff Checkpoints and RBT
   Sobriety checkpoints and RBT, when well publicized, are highly effective in reducing alcohol-related crashes but are underused because of staffing requirements. Research has shown that checkpoints with a smaller number of officers can be equally successful, particularly if the officers use passive sensors to detect drinking. Low-staff checkpoints equipped with passive sensors conducted on a weekly basis in numerous communities in the US and countries around the world would have a substantial effect on impaired-driving fatal crashes.

   Canada's federal government recently introduced an RBT program that allows drivers to be breath-tested at any time and in any place on their roads. If RBT is successful and effective in Canada, this could affect similar legislation in the US.

2. Reduce the BAC Limit for Driving to .05 g/dL
   Virtually all drivers are impaired with regard to driving performance at .05 g/dL BAC. Laboratory and test track research shows that the vast majority of drivers, even experienced drinkers who typically reach BACs of .15 g/dL or greater, are impaired at .05 g/dL BAC and higher with regard to critical driving tasks, as discussed in Section II above. Further, the risk of being involved in a crash rises

very rapidly after a driver reaches or exceeds .05 g/dL BAC, compared to drivers with no alcohol in their blood systems. Recent studies indicate that the relative risk of being killed in a single-vehicle crash for drivers with BACs of .05 to .079 g/dL is at least 7 times that of drivers at .00 g/dL BAC (no alcohol) and could be as much as 21 times that of drivers at .00 g/dL BAC depending on the age of the driver [193,213].

Lowering the limit for legal driving to .05 g/dL BAC is a proven-effective countermeasure that has reduced alcohol-related traffic fatalities in several countries, most notably Australia. While studies in Europe and Australia use different methodologies to evaluate these effects, the evidence is consistent and persuasive that fatal and injury crashes involving drinking drivers decrease on the order of at least 5%–8% and up to 18% after a country lowers their BAC limit from .08 to .05 g/dL BAC [21,85,135]. A metaanalysis of international studies on lowering the BAC limit in general found a 5.0% decline in nonfatal alcohol-related crashes, a 9.2% decline in fatal alcohol-related crashes from lowering the BAC from .10 to .08 g/dL, and an 11.1% decline in fatal alcohol-related crashes from lowering the BAC to .05 g/dL or lower. The study estimated that 1,790 lives would be saved each year if all states in the US adopted a .05 g/dL BAC limit [49].

A .05 g/dL BAC is a reasonable standard to set. A .05 g/dL BAC is not typically reached with a couple of beers after work or with a glass of wine or two with dinner. It takes at least four US standard drinks (i.e., 12 oz. of beer at 5% alcohol; 5 oz. of wine at 12% alcohol; 1.5 oz. of distilled spirits at 40% alcohol; all equal 0.60 oz. of alcohol per drink) for the average 170-lb male to exceed .05 g/dL BAC in 2 h on an empty stomach (three drinks for the 137-lb female) [139]. The BAC level reached depends on a person's age, gender, weight, whether there is food in their stomach, and their metabolism rate [139]. No matter how many drinks it takes to reach .05 g/dL BAC, people at this level are too impaired to drive safely [126].

The US public generally supports levels below .08 g/dL BAC. NHTSA surveys show that most people would not drive after consuming two or three drinks in an hour and believe the limit should be no higher than the BAC level associated with that [153]. That would be .05 g/dL BAC or lower for most drivers. A recent survey indicated that 63% of drivers in the US support lowering the illegal BAC from .08 to .05 g/dL [4].

Most industrialized nations around the world have set BAC limits at .05 g/dL BAC or lower. All states in Australia now have a .05 g/dL BAC limit. France, Austria, Italy, Spain, and Germany lowered their limit to .05 g/dL BAC, while Sweden, Norway, Japan, and Russia have set their limit at .02 g/dL BAC [209].

Further progress is needed in reducing alcohol-impaired driving in the US and in many countries around the world. Progress in reducing impaired driving has stalled over the past 20 years in several countries [30,42]. Lowering the BAC limit from .08 to .05 g/dL will serve as a general deterrent to all those who drink and drive by indicating that the government is getting tougher on impaired driving and society will not tolerate impaired drivers [54]. Such legislation typically reduces the number of drinking drivers involved in fatal crashes at all BAC levels (BACs ≥.01 g/dL; BACs ≥.05 g/dL; BACs ≥.08 g/dL; BACs ≥.15 g/dL) [80,192,197].

At the time of publication, Utah was the only state in the US that had lowered its BAC limit from .08 to .05 g/dL. However, several states had introduced legislation to lower the limit to .05 g/dL, including California and New York. Utah did not change their DUI enforcement strategy for .05 g/dL BAC; it is the same as it was for .08 g/dL BAC. A new standardized field sobriety test (SFST) will need to be developed and validated at .05 g/dL BAC.

C. Future Opportunities in Tertiary Prevention

1. Interlock Alternative Programs: Secure Continuous Remote Alcohol Monitoring (SCRAM) and NO-DRIV Ankle Bracelet that Detects Driving

Ignition interlocks are highly effective in reducing offender recidivism [181], but only a small portion of the eligible DUI offenders can be motivated to install them. An alternative to the interlock program is needed for those offenders without cars or who are willing to take the risk of driving illicitly rather than installing the interlock, because experience shows that offenders do continue to drive and become involved in crashes. Monitoring offenders' BACs appears to be an effective alternative to the interlock.

On the horizon is a developing technology that detects driving via an ankle bracelet with accelerometers that measure the foot movements required to operate a vehicle. When perfected, this will allow the court to monitor offenders to ensure they are not driving. This could be offered as an alternative to the interlock. Programs need to be created that require electronically monitored abstinence or electronically monitored driving as alternatives to the interlock. More offenders will then decide to choose the interlock instead of the other more stringent alternatives.

D. Silver Bullet: Cars that Drunks Can't Drive

1. Driver Alcohol-Detection System for Safety Program

A long-term development program has been inaugurated by the NHTSA, automobile manufacturers, and MADD to develop a system for all cars that can passively sense the BAC of the driver and prevent ignition of the vehicle's motor if the driver is over the BAC legal limit. The program is called Driver Alcohol-Detection System for Safety (DADSS) and is currently being funded by the NHTSA and most of the motor vehicle manufacturers. If such a vehicle can be produced, it would finally fulfill the objective enunciated 50 years ago — to build "Cars that Drunks Can't Drive" [179]. One of these monitors passively detects alcohol in the breath of the driver, making it unnecessary for the driver to blow into an interlock breath tube. Another developing technology measures BAC passively through the skin, providing a substitute for blowing into the interlock [38].

These systems may have value as a method for activating a driver interlock system only when there is evidence of a drinking driver in the vehicle. Thus, the not-too-distant future offers the possibility of equipping all new vehicles with a system that would make impaired driving less likely.

2. Autonomous Vehicles

New automated in-vehicle technologies are being developed and deployed to counteract driver errors and prevent crashes. Automated driver systems (ADSs) are a class of vehicle technologies that provide drivers timely warnings and/or actions. Some ADSs actively and automatically intervene to avoid hazardous situations.

Many manufacturers offer these technologies as options on some or all of their vehicles, and may offer these systems as standard in the future. ADS technologies are the precursor to autonomous vehicles and, depending on the combination of ADS equipment installed in a vehicle, can allow autonomous driving at the present time [1,155]. Currently, the effectiveness of each crash-avoidance technology relies on both the presence of the technology and the appropriate responses from drivers [16,89]. In many cases, drivers may be unaware of the presence of the system within their car or may not fully understand its performance limits in terms of objects detected, speed of operation, or conditions where degraded performance is expected [6]. Since near-collisions are rare events, owners may rarely experience audible, visual, or haptic feedback and may not appropriately respond. Nomenclature and branding for each system also pose serious challenges since each carmaker may choose a name for marketing purposes that differs from other brands or even other vehicles in their fleet, making it harder for drivers to learn about the capabilities of the systems in their vehicles.

To achieve optimal safety, it is important for drivers to understand their vehicles and appropriately rely on ADSs for safe navigation. Today, drivers are educated about their vehicles in a number of ways including: (a) mainstream media; (b) original equipment manufacturers (OEM) websites and educational material; and (c) dealership experiences [1]. Several OEMs have implemented

programs to educate new vehicle drivers. For example, Toyota currently integrates an overview of safety systems including Toyota Safety Sense in their vehicle overview. Toyota also equips all dealerships with handheld and large-format touchpads to allow existing and future customers to explore the content and performance of systems offered in each new car.

Studies are needed to determine if automated features will help impaired drivers avoid crashes and to monitor the performance of autonomous vehicles as they become available.

CONCLUSION: WHERE DO WE GO FROM HERE?

In January 2018, the National Academy of Sciences, Engineering, and Medicine in the US released a comprehensive report on accelerating progress to reduce alcohol-impaired driving fatalities in the US [136,170]. The report (written by a highly qualified committee assembled to review the impaired-driving problem) provides a blueprint to solving the problem by identifying evidence-based and promising policies, programs, strategies, and system changes to increase progress in reducing alcohol-impaired drivers' traffic fatalities.

Among many other recommendations, those pertinent to this article include the following:

- Jurisdictions should adopt and/or strengthen laws and dedicate enforcement resources to stop illegal alcohol sales (i.e., sales to already intoxicated adults and sales to underage persons).
- Law enforcement agencies should conduct sobriety checkpoints in conjunction with widespread publicity to promote awareness of these enforcement initiatives.
- Municipalities should support policies and programs that increase the availability, convenience, affordability, and safety of transportation alternatives for drinkers who might drive otherwise. This includes permitting transportation network company ride-sharing, enhancing public transportation options (especially during night-time and weekend hours), and boosting or incentivizing transportation alternatives in rural areas.
- Implement DUI courts that include available consultation or referral for evaluation by an addiction-trained clinician.
- All-offender, alcohol-detecting, ignition-interlock laws should be enacted. To increase effectiveness, jurisdictions should consider increased monitoring periods based on the offender's BAC at the time of arrest and past recidivism.
- Laws against alcohol-impaired driving should be enacted defining impairment at 0.05 BAC, and enactment should be accompanied by media campaigns and robust and visible enforcement efforts.

For developing countries with high traffic-fatality rates, the cost of those deaths and injuries is draining their economies. It will be cost-effective for them to use limited resources to reduce drunk-driving crashes. Drunk driving should be illegal in every country of the world and it should be based on the driver's BAC. Setting a BAC limit for the general population of .05 g/dL or lower will be a good start.

Conducting RBT and/or sobriety checkpoints is an enforcement strategy that is effective in every country if it is done frequently and if it is visible and it is publicized.

For high-income countries, doubling down on what works and taking advantage of new technologies should be the norm. Technologies that passively detect BACs of motor vehicle operators have great potential to reduce impaired driving in the future.

While numerous countries have made progress in reducing drunk driving, much more work must be accomplished. Drunk-driving laws and their serious enforcement have been effective in most countries and have an immediate effect. A general deterrent effect (i.e., deter all drivers from drunk driving) gives the "biggest bang for the buck" in countermeasures and is cost-effective. A general approach to deterrence affecting all drivers involves laws, enforcement, reasonable sanctions, and publicity. Specific deterrence (i.e., affecting only drivers arrested for drunk driving and providing sanctions against repeating the behavior) works to some extent but does not have the magnitude of impact that a general deterrent strategy has.

It will most likely take a combination of strategies for drunk driving to be reduced in countries around the world. But for that to happen, some priority to deterring drunk driving must be established by key country officials. Data, analysis, and evaluations of specific strategies will be key needs. If countries can obtain measures of the BACs of drivers involved in fatal crashes and of drivers on the roads, those data will be extremely informative. Information on arrests and convictions for drunk driving will also provide important information. Countries must collect vital information that can be used to assess and bolster progress in reducing drunk driving.

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REFERENCES

1. Abraham H, McAnulty H, Mehler B, Reimer B: Case study of today's automotive dealerships: Introduction and delivery of advanced driver assistance systems; *Transport Res Rec* (Journal of the Transportation Research Board) 2660:7; 2017; *https://doi.org/10.3141/2660-02* (Accessed May 22, 2019).

2. Anglin L, Caverson R, Fennel R, Giesbrecht N, Mann RE: *A Study of Impaired Drivers Stopped by Police in Sudbury*; Addiction Research Foundation: Ontario, Canada; 1997.

3. Apsler R, Char AR, Harding WM, Klein TM: *The Effects of .08 BAC Laws*; US National Highway Traffic Safety Administration: Washington, DC; 1999.

4. Arnold LS, Tefft BC: *Driving Under the Influence of Alcohol and Marijuana: Beliefs and Behaviors, United States, 2013–2015*; AAA Foundation for Traffic Safety: Washington, DC; 2016.

5. Arnold R: *Effect of Raising the Legal Drinking Age on Driver Involvement in Fatal Crashes: The Experience of Thirteen States* (DOT HS 806 902); US National Highway Traffic Safety Administration: Washington, DC; 1985.

6. Aziz T, Horiguchi Y, Sawaragi T: An empirical investigation of the development of driver's mental model of a lane departure warning system while driving; *Proceedings — 12th Symposium on Analysis, Design, and Evaluation of Human-Machine Systems*; Las Vegas, VA; August 11–15; 2013.

7. Bartl G, Esberger R: Effects of lowering the legal BAC limit in Austria; In Laurell H, Schlyter F (Eds): *Proceedings — 15th International Conference on Alcohol, Drugs and Traffic Safety* (T'2000); Stockholm, Sweden; May 22–26, 2000.

8. Beirness D, Simpson H, Mayhew D, Jonah B: The impact of administrative license suspension and vehicle impoundment for driving under the influence in Manitoba; In Mercier-Guyon C (Ed): *Proceedings — 14th International Conference on Alcohol, Drugs and Traffic Safety*; Annecy, France; September 21–26, 1997.

9. Beitel GA, Sharp MC, Glauz WD: Probability of arrest while driving under the influence of alcohol; *Inj Prev* 6:158; 2000.

10. Berning A, Compton R, Wochinger K: *Results of the 2013–2014 National Roadside Survey of Alcohol and Drug Use by Drivers* (DOT HS 812 118); US National Highway Traffic Safety Administration: Washington, DC; 2015.

11. Birckmayer J, Hemenway D: Minimum-age drinking laws and youth suicide, 1970–1990; *Am J Public Health* 89:1365; 1999.

12. Block A: *Survey of DWI Courts* (DOT HS 812 283); US National Highway Traffic Safety Administration: Washington, DC; 2016.

13. Blomberg RD: *Lower BAC Limits for Youth: Evaluation of the Maryland .02 Law* (DOT HS 806 807); US National Highway Traffic Safety Administration: Washington, DC; 1992.

14. Blomberg RD, Peck RC, Moskowitz H, Burns M, Fiorentino D: *Crash Risk of Alcohol Involved Driving: A Case-Control Study* (Final Report); Dunlap & Associates: Stamford, CT; 2005.

15. Blomberg RD, Peck RC, Moskowitz H, Burns M, Fiorentino D: The Long Beach/Fort Lauderdale relative risk study; *J Safety Res* 40:285; 2009.

16. Blower D: *Assessment of the Effectiveness of Advanced Collision Avoidance Technologies* (UMTRI-2014-3); University of Michigan Transportation Research Institute: Ann Arbor, MI; 2014.

17. Borkenstein RF: Problems of enforcement, adjudication and sanctioning; In Israelstam S, Lambert S (Eds): *Proceedings — 6th International Conference on Alcohol, Drugs and Traffic Safety Alcohol, Drugs and Traffic Safety*; Toronto, Ontario; September 8–13, 1975.

18. Borucki K, Schreiner R, Dierkes J, Jachau K, Krause D, Westphal S, Wurst FM, Luley C, Schmidt-Gayk H: Detection of recent ethanol intake with new markers: Comparison of fatty acid ethyl esters in serum and of ethyl glucuronide and the ration if 5-hydroxytryptophol to 5-hydroxyindole acetic acid in urine; *Alcohol Clin Exp Res* 29:781; 2005.

19. Brazil N, Kirk DS: Uber and metropolitan traffic fatalities in the United States; *Am J Epidemiol* 183:192; 2016.

20. Breckenridge JF, Winfree LT, Maupin JR, Clason DL: Drunk drivers, DWI "Drug Court" treatment, and recidivism: Who fails? *JRP* 2:87; 2000.

21. Brooks C, Zaal D: Effects of a reduced alcohol limit in driving; In Utzelmann HD, Berghous G, Kroj G (Eds): *Alcohol, Drugs and Traffic Safety*; Verlag TÜV Rheinland: Cologne, Germany; p 860; 1993.

22. Brown DB, Maghsoodloo SA: A study of alcohol involvements in young driver accidents with the lowering of the legal age of drinking in Alabama; *Accid Anal Prev* 13:319; 1981.

23. Chen LH, Baker SP, Li G: Graduated driver licensing programs and fatal crashes of 16-year-old drivers: A national evaluation; *Pediatrics* 118:56; 2006.

24. Christophersen AS, Morland JG, Stewart K: International trends in alcohol and drug use among motor vehicle drivers; *Forensic Sci Rev* 28:37; 2016.

25. Clark WB, Hilton ME: *Alcohol in America: Drinking Practices and Problems*; State University of New York Press: Albany, NY; 1991.

26. Compton RP: Preliminary analysis of the effect of selected citizen group court monitoring programs; *J Traffic Safety Educ* 35(1):8; 1987.

27. Compton RP, Berning A: *Drug and Alcohol Crash Risk* (DOT HS 812 117); US National Highway Traffic Safety Administration: Washington, DC; 2015.

28. Cook PJ, Tauchen G: The effect of minimum drinking age legislation on youthful auto fatalities, 1970–1977; *J Leg Stud* 13:169; 1984.

29. Cornwell EE, Belzberg H, Velmahos G, Chan LS, Demetriades D, Stewart BM, Oder DB, Kahaku D, Asensio JA, Berne TV: The prevalence and effect of alcohol and drug abuse on cohort-matched critically injured patients; *Am Surg* 64:461; 1998.

30. Dang JN: *Statistical Analysis of Alcohol-Related Driving Trends, 1982–2005* (DOT HS 810 942); US National Highway Traffic Safety Administration: Washington, DC; 2008.

31. Dee TS, Grabowski DC, Morrisey MA: Graduated driver licensing and teen traffic fatalities; *J Health Econ* 24:571; 2005.

32. Dills AK, Mulholland S: Ride-sharing, fatal crashes, and crime; *South Econ J* 84:965; 2016.

33. Ditsuwan V, Veerman JL, Bertram M, Vos T: Cost-effectiveness of interventions for reducing road traffic injuries

related to driving under the influence of alcohol; *Value Health* 16(1):23; 2013.

34. Ditsuwan V, Veerman JL, Bertram M, Vos T: Sobriety checkpoints in Thailand: A review of effectiveness and developments over time; *Asia Pac J Public Health* 27(2):1; 2011.

35. Eby DW: The convicted drunk driver in Michigan: A profile of offenders; *UMTRI Research Review* 25(5):1; 1995.

36. Editorial: *Quart Inebriety* 26:308; 1904.

37. Elder RW, Shults RA, Sleet DA, Nichols JL, Zaza S, Thompson RS: Effectiveness of sobriety checkpoints for reducing alcohol-involved crashes; *Traffic Inj Prev* 3:266; 2002.

38. Ennis M: Impairment detection of Lumidigm's biometric platform; *Mothers Against Drunk Driving Technology Symposium*: Albuquerque, NM; 2006.

39. Epperlein T: Initial deterrent effects of the crackdown on drunken drivers in the state of Arizona; *Accid Anal Prev* 19:271; 1987.

40. Farmer CM, Wells JK, Ferguson SA, Voas RB: Field evaluation of the PAS III passive alcohol sensor; *Traffic Inj Prev* 1:55; 1999.

41. Federal Bureau of Investigation: *Uniform Crime Reporting Handbook*; US Department of Justice: Washington, DC; *https://ucr.fbi.gov/about-us/cjis/ucr/crime-in-the-u.s/* (Accessed May 22, 2019).

42. Fell JC, Beirness, J, Voas RB, Smith GS, Jonah B, Maxwell JC, Price J, Hedlund J: Can progress in reducing alcohol-impaired driving fatalities be resumed? Results of a workshop sponsored by the Transportation Research Board, Alcohol, Other Drugs, and Transportation Committee (ANB50); *Traffic Inj Preven* 17:771; 2016.

43. Fell JC, Compton C, Voas RB: A note on the use of passive alcohol sensors during routine traffic stops; *Traffic Inj Prev* 9:534; 2008.

44. Fell JC, Fisher DA, Voas RB, Blackman K, Tippetts AS: The relationship of underage drinking laws to reductions in drinking drivers in fatal crashes in the United States; *Accid Anal Prev* 40:1430; 2008.

45. Fell JC, Fisher D, Yao J, McKnight S: Evaluation of a responsible beverage service and enforcement program: Effects on bar patron intoxication and potential impaired driving by young adults; *Traffic Inj Prev* 16:557; 2017.

46. Fell JC, Lacey JH, Voas RB: Sobriety checkpoints: Evidence of effectiveness is strong, but use is limited; *Traffic Inj Prev* 5:220; 2004.

47. Fell JC, Romano E, Voas RB: A national evaluation of graduated driver licensing laws in the United States; *Proceedings — 20th International Conference on Alcohol, Drugs and Traffic Safety*; Brisbane, Australia; August 25–28, 2013.

48. Fell JC, Scherer M: Administrative license suspension: Does length of suspension matter? *Traffic Inj Prev* 18:577; 2017.

49. Fell JC, Scherer M: Estimation of the potential effectiveness of lowering the blood alcohol concentration (BAC) limit for driving from .08 to .05 grams per deciliter in the United States; *Alcohol Clin Exp Res* 41:2128; 2017.

50. Fell JC, Scherer M, Thomas S, Voas RB: Assessing the impact of twenty underage drinking laws; *J Stud Alcohol Drugs* 77:249; 2016.

51. Fell JC, Tippetts AS, Ciccel JD: An evaluation of three

52. Fell JC, Todd M, Voas, RB: A national evaluation of the nighttime and passenger restricted components of graduated driver licensing; *J Safety Res* 42:283; 2011.

53. Fell JC, Voas RB: Mothers Against Drunk Driving (MADD): The first 25 years; *Traffic Inj Prev* 7:195; 2006.

54. Fell JC, Voas RB: The effectiveness of a 0.05 blood alcohol concentration (BAC) limit for driving in the United States; *Addiction* 109:869; 2014.

55. Fell JC, Voas RB: The effectiveness of reducing illegal blood alcohol concentration limits for driving: Evidence for lowering the limit to .05 BAC; *J Safety Res* 37:233; 2006.

56. Fell JC, Waehrer G, Voas RB, Auld-Owens A, Carr K, Pell K: Relationship of impaired-driving enforcement intensity to drinking and driving on the roads; *Alcohol Clin Exp Res* 39:84; 2015.

57. Ferguson SA, Wells JK, Lund AK: The role of passive alcohol sensors in detecting alcohol-impaired drivers at sobriety checkpoints; *Alcohol Drugs Driving* 11:23; 1995.

58. Ferrara SD, Zancaner S, Georgetti R: Low blood alcohol levels and driving impairment. A review of experimental studies and international legislation; *Inter J Legal Med* 106:169; 1994.

59. Ferreira J, Sickerman A: The impact of Massachusetts' reduced drinking age on auto accidents; *Accid Anal Prev* 8:229; 1976.

60. Fleming MF, Mundt MP, French MT, Manwell LB, Stauffacher EA, Barry KL: Brief physician advice for problem drinkers: Long-term efficacy and benefit-cost analysis; *Alcohol Clin Exp Res* 26:36; 2002.

61. Foss R, Goodwin A: Enhancing the effectiveness of graduate driver licensing legislation; *J Safety Res* 34:79; 2003.

62. Foss RD, Feaganes JR, Roggman LA: Initial effects of graduated driver licensing on 16-year-old driver crashes in North Carolina; *JAMA* 286:1631; 2001.

63. Foss RD, Stewart JR, Reinfurt DW: *Evaluation of the Effects of North Carolina's 0.08% BAC Law*; US National Highway Traffic Safety Administration: Washington, DC; 1998.

64. Freeman-Wilson K, Wilkosz MP: *Drug Court Publications Resource Guide*, 4th ed; US National Drug Court Institute: Alexandria, VA; 2002.

65. Friend K, Levy DT: Reductions in smoking prevalence and cigarette consumption associated with mass-media campaigns; *Health Educ Res* 17:85; 2002.

66. Gentilello LM, Ebel BE, Wickizer TM, Salkever DS, Rivara FP: Alcohol interventions for trauma patients treated in emergency departments and hospitals: A cost benefit analysis; *Ann Surg* 241:541; 2005.

67. Gentilello LM, Rivara FP, Donovan DM, Jurkovich GJ, Daranciang ED, Christopher W, Villaveces A, Copass M, Ries RR: Alcohol interventions in a trauma center as a means of reducing the risk of injury recurrence; *Ann Surg* 230:473; 1999.

68. Gjerde H, Ramaekers JG, Mørland JG: Methodologies for establishing the relationship between alcohol/drug use and driving impairment — Differences between epidemiological, experimental, and real-case studies; *Forensic Sci Rev* 31:141; 2019.

69. Gjerde H, Strand MC, Morland JG: Driving under the

driving-under-the-influence courts in Georgia; *Ann Adv Automot Med* 55:301; 2011.

influence of non-alcohol drugs — An update Part I: Epidemiological studies; *Forensic Sci Rev* 27:89, 2015.

70. Goodwin A, Thomas L, Kirley B, Hall W, O'Brien N, Hill K: *Countermeasures That Work: A Highway Safety Countermeasure Guide for State Highway Safety Offices*, 8th ed (DOT HS 812 202); US National Highway Traffic Safety Administration: Washington, DC; 2015.

71. Graham K, Osgood DW, Zibrowski E, Purcell J, Gilksman L, Leonard K, Pemanen K, Saltz RF, Toomey TL: The effect of the safer bars programme on physical aggression in bars: Results of a randomized controlled trial; *Drug Alcohol Rev* 23:31; 2004.

72. Guerin P, Pitts WJ: *Evaluation of the Bernalillo County Metropolitan DWI/Drug Court: Final Report;* University of New Mexico Center for Applied Research and Analysis: Albuquerque, NM; 2002.

73. Hagen R: *The Effectiveness of License Suspension or Revocation for Drivers Convicted of Multiple Driving Under the Influence Offenses* (Report #59); California Department of Motor Vehicles: Sacramento, CA; 1977.

74. Hause JM, Voas RB, Chavez E: Conducting voluntary roadside surveys: The Stockton experience; In Valverius MR (Ed): *Proceedings — 8th International Conference on Alcohol, Drugs and Traffic Safety*; Umea, Sweden; June 23–25. 1982.

75. Hedlund JH, Ulmer RG, Preusser DF: *Determine Why There are Fewer Young Alcohol-Impaired Drivers* (DOT HS 809 348); US Department of Transportation: Washington, DC; 2001.

76. Helander A, Beck O: Ethyl sulfate: A metabolite of ethanol in humans and a potential biomarker of acute alcohol intake; *J Anal Toxicol* 29:270; 2005.

77. Henstridge J, Homel R, Mackay P: *The Long-Term Effects of Random Breath Testing in Four Australian States: A Time Series Analysis*; Federal Office of Road Safety: Canberra, Australia; 1997.

78. Hingson R, Heeren T, Winter M: Effects of recent 0.08% legal blood alcohol limits on fatal crash involvement; *Inj Prev* 6:109; 2000.

79. Hingson R, Heeren T, Winter M: Lower legal blood alcohol limits for young drivers; *Public Health Rep* 109:739; 1994.

80. Hingson R, Heeren T, Winter M: Lowering state legal blood alcohol limits to 0.08 percent: The effect on fatal motor vehicle crashes; *Am J Public Health* 86:1297; 1996.

81. Hingson R, Howland J, Heeren T, Winter M: Reduced BAC limits for young people (impact on night fatal) crashes; *Alcohol Drugs Driving* 7:117; 1992.

82. Hingson R, Scotch N, Mangione T, Meyers A, Glantz L, Heeren T, Lin N, Mucatel M, Pierce G: Impact of legislation raising the legal drinking age in Massachusetts from 18 to 20; *Am J Public Health* 73:63; 1983.

83. Holder H, Treno AJ: Media advocacy in community prevention: News as a means to advance policy change; *Addiction* 92:S189; 1997.

84. Holder HD, Wagenaar AC: Mandated server training and reduced alcohol-involved traffic crashes: A time series analysis of the Oregon experience; *AcciD Anal Prev* 26:89; 1994.

85. Homel R: Drink-driving law enforcement and the legal blood alcohol limit in New South Wales; *Accid Anal Prev* 26:147; 1994.

86. Homel R: *Policing and Punishing the Drinking Driver — A Study of General and Specific Deterrence*; Springer-Verlag: New York, NY; 1988.

87. Howat P, Sleet D, Smith I: Alcohol and driving: Is the 0.05% blood alcohol concentration limit justified? *Drug Alcohol Rev* 10:151; 1991.

88. Huddleston CW, Marlowe DB, Casebolt R: *Painting the Current Picture: A National Report Card on Drug Courts and Other Problem-Solving Court Programs in the United States;* National Drug Court Institute, Bureau of Justice Assistance: Washington, DC; 2008.

89. Jermakian JS: Crash avoidance potential of four passenger vehicle technologies; *Accid Anal Prev* 43:732; 2011.

90. Johnson D, Fell JC: The impact of lowering the illegal BAC limit to .08 in five states in the U.S.; *Ann Adv Automot Med* 39:45; 1995.

91. Johnsson KO, Berglund M: Education of key personnel in student pubs leads to a decrease in alcohol consumption among the patrons: A randomized controlled trial; *Addiction* 98:627; 2003.

92. Jones AW: The analysis of ethanol in blood and breath for legal purposes — A historical review; *Forensic Sci Rev* 8:13; 1996.

93. Jones L, Hughes K, Atkinson AM, Bellis MA: Reducing harm in drinking environments: A systematic review of effective approaches; *Health Place* 17:508; 2011.

94. Jones NE, Pieper CF, Robertson LS: The effect of legal drinking age on fatal injuries of adolescents and young adults; *Am J Public Health* 82:112; 1992.

95. Jones R, Lacey J: *Alcohol and Highway Safety 2001: A Review of the State of Knowledge* (DOT HS 809 383); US National Highway Traffic Safety Administration: Washington, DC; 2001.

96. Kenkel DS: Drinking, driving and deterrence: The effectiveness and social costs of alternative policies; *JL & Econ* 36:877; 1993.

97. Kilmer B, Nicosia N, Heaton P, Midgette, G: Efficacy of frequent monitoring with swift, certain, and modest sanctions for violations: Insights from South Dakota's 24/7 sobriety project; *Am J Public Health* 103:37; 2013.

98. Kindelberger J: *Calculating Lives Saved Due to Minimum Drinking Age Laws* (Traffic Safety Facts Research Note); US National Center for Statistics and Analysis: Washington, DC; 2005.

99. Klein TM: *Changes in Alcohol-Involved Fatal Crashes Associated with Tougher State Alcohol Legislation* (DOT HS 807 511); US National Highway Traffic Safety Administration: Washington, DC; 1989.

100. Klein TM, Walz MC: *Estimating Alcohol Involvement in Fatal Crashes in Light of Increases in Restraint Use*; US National Highway Traffic Safety Administration, National Center for Statistics and Analysis: Washington, DC; 1998.

101. Klepp KI, Schmid LA, Murray DM: Effects of the increased minimum drinking age law on drinking and driving behavior among adolescents; *Addict Res* 4:237; 1996.

102. Knoebel K, Ross HL: *Effects of Administrative License Revocation on Employment* (DOT HS 808 462); US National Highway Traffic Safety Administration: Washington, DC; 1996.

103. Kypri K, Voas RB, Langley JD, Stephenson SCR, Begg DJ, Tippetts AS, Davie GS: Minimum purchasing age for alcohol and traffic crash injuries among 15- to 19- year-olds in New Zealand; *Am J Public Health* 96:126; 2006.

104. Lacey J, Jones R, Stewart J: *Cost-Benefit Analysis of Administrative License Suspension* (DOT HS 807 689); US National Highway Traffic Safety Administration: Washington, DC; 1991.

105. Lacey JH, Kelley-Baker T, Furr-Holden D, Voas RB, Romano E, Torres, P, Tippetts AS, Ramirez A, Brainard K, Berning A: *2007 National Roadside Survey of Alcohol and Drug Use by Drivers: Alcohol Results* (Report No. DOT HS 811 248); US National Highway Traffic Safety Administration: Washington, DC; 2009.

106. Lacey JH, Rudisill LC, Popkin CL, Stewart JR: Education for drunk drivers: How well has it worked in North Carolina? *Pop Gov* 51:44; 1986.

107. Lacey J, Stewart J, Marchetti L, Jones R: *Assessment of the Effects of Implementing and Publicizing Administrative License Revocation for DWI in Nevada*; US National Highway Traffic Safety Administration: Washington, DC; 1990.

108. Lange JE, Voas, RB: Patterns of border crossings associated with Tijuana binge drinking by U.S. young people; *1998 Scientific Meeting of the Research Society on Alcoholism*: Hilton Head Island, SC; June 20–25, 1998.

109. Lestina DC, Lund AK: *Laboratory Evaluation of Two Passive Alcohol Sensors*; Insurance Institute for Highway Safety: Arlington, VA ;1989.

110. Levy D, Asch P, Shea D: An assessment of county programs to reduce driving while intoxicated; *Health Educ Res*; 5:247; 1990.

111. Levy D, Shea D, Asch P: Traffic safety effects of sobriety checkpoints and other local DWI programs in New Jersey; *Am J Public Health* 79:291;1988.

112. Loudenburg R, Drube G, Leonardson G: *South Dakota 24-7 Sobriety Program Evaluation Findings Report*; Mountain Plains Evaluation: Salem, SD; 2010.

113. Lund AF, Jones IS: Detection of impaired drivers with a passive alcohol sensor; In Noordzij PC, Roszbach R (Eds): *Alcohol, Drugs and Traffic Safety 'T86*; Excerpta Medica: New York, NY; P 379; 1987.

114. Lund AK, Kiger S, Lestina D, Blackwell T: Using passive alcohol sensors during police traffic stops; *70th Annual Meeting of Transportation Research Board*; Transportation Research Board: Washington, DC; 1991.

115. Maio RF, Waller PF, Blow FC, Hill FM, Singer KM: Alcohol abuse/dependence in motor vehicle crash victims presenting to the emergency department; *Acad Emerg Med* 4:256; 1997.

116. Mann R, Smart R, Stoduto G, Beirness D, Lamble R, Vingilis E: The early effects of Ontario's Administrative Driver's License Suspension Law on driver fatalities with BAC >80 mg%; *Can J Public Health* 93:176; 2002.

117. Marques PR, McKnight AS: *Evaluating Transdermal Alcohol Measuring Devices*; US National Highway Traffic Safety Administration: Washington, DC; 2007.

118. Marshall M, Oleson A: MADDer than hell; *Qual Health Res* 6:6; 1996.

119. Masten SV, Foss RD, Marshall SW: Graduated driver licensing and fatal crashes involving 16- to 19-year-old drivers; *JAMA* 306:1098; 2011.

120. Mayhew DR, Simpson HM, Pak A: Changes in collision rates among novice drivers during the first months of driving; *Accid Anal Prev* 35:683; 2003.

121. McCarthy JD, Wolfson M: Resources mobilization by social movement organizations: Agency, strategy, and organization in the movement against drinking and driving; *Am Sociol Rev* 61:1070; 1996.

122. McCarthy JD, Wolfson M, Harvey DS: *Chapter Survey Report of the Project on the Citizens' Movement Against Drunk Driving*; The Catholic University of America Center for the Study of Youth Development: Washington, DC; 1987.

123. McCarthy PS, Ziliak J: Effect of MADD on drinking-driving activities: An empirical study; *Appl Econ* 22:1215; 1990.

124. McCartt AT, Shabanova VI, Leaf WA: Driving experience, crashes and traffic citations of teenage beginning drivers; *Accid Anal Prev* 35:311; 2003.

125. McCartt AT, Teoh ER, Fields M, Braitman KA, Hellinga LA: *Graduated Licensing Laws and Fatal Crashes of Teenage Drivers: A National Study*; Insurance Institute for Highway Safety: Arlington, VA; 2009.

126. McKnight AJ, Langston E, McKnight AS, Lange J: Sobriety tests for low blood alcohol concentrations; *Accid Anal Prev* 34:305; 2002.

127. McKnight AJ, Voas R: The effect of license suspension on DUI recidivism; *Alcohol Drugs Driving* 7:43; 1991.

128. Mello MJ, Nirenberg TD, Longabaugh R, Woolard R, Minugh AP, Becker B, Baird J, Stein L: Emergency department brief motivational interventions for alcohol with motor vehicle crash patients; *Ann Emerg Med* 45:620; 2005.

129. Merki D, Lingg M: Combating the drunk driving problem through community action: A proposal; J Alcohol Drug Educ 32(3):42; 1987.

130. Miller TR, Galbraith M, Lawrence BA: Costs and benefits of a community sobriety checkpoint program; *J Stud Alcohol* 59:465; 1998.

131. Monti PM, Colby SM, Barnett NP, Spirito A, Rhsenow DJ, Myers M, Woolard R, Lewander W: Brief intervention for harm reduction with alcohol-positive older adolescents in a hospital emergency department; *J Consult Clin Psychol* 67:989; 1999.

132. Moskowitz H, Burns M, Fiorentino D, Smiley A, Zador P: *Driver Characteristics and Impairment at Various BACs* (DOT HS 809 075); US National Highway Traffic Safety Administration: Washington, DC; 2000.

133. Moskowitz H, Fiorentino D: *A Review of the Literature on the Effects of Low Doses of Alcohol on Driving-Related Skills* (DOT HS 809 028); US National Highway Traffic Safety Administration: Washington, DC; 2000.

134. Moulden JV, Russell A: Is it MADD trying to rate the states? A citizen activist approach to DWI prevention; *Alcohol Drugs Driving* 10:317; 1994.

135. Nagata T, Setoguchi S, Hemenway D, Perry MJ: Effectiveness of a law to reduce alcohol-impaired driving in Japan; *Inj Prev* 14:19; 2008.

136. National Academies of Sciences, Engineering and Medicine: *Getting to Zero Alcohol-Impaired Driving Fatalities: A Comprehensive Approach to a Persistent Problem*; The National Academies Press: Washington, DC; 2018.

137. National Center for Statistics and Analysis: *Traffic Safety Facts: 2005 Data — Young Drivers* (DOT HS 810 630); US National Highway Traffic Safety Administration: Washington, DC; 2005.

138. National Highway Traffic Safety Administration: *Admi-*

nistrative License Revocation: Resource Manual (DOT HS 807 873); US National Highway Traffic Safety Administration: Washington, DC; 1992.

139. National Highway Traffic Safety Administration: *Computing a BAC Estimate*; US Department of Transportation: Washington, DC; 1994.

140. National Highway Traffic Safety Administration: *Fatality Analysis Reporting System (FARS)*; US National Highway Traffic Safety Administration; *ftp://ftp.nhtsa.dot.gov/fars/* (Accessed May 15, 2019).

141. National Highway Traffic Safety Administration, American College of Emergency Physicians: *Alcohol Screening and Brief Intervention in the Medical Setting*; US Department of Transportation: Washington, DC: 2002; *http://www.nhtsa.dot.gov/people/injury/ems/alcohol_screening/Overview.html* (Accessed May 15, 2019).

142. National Institute on Alcohol Abuse and Alcoholism: *Alcohol Policy Information System (APIS)*; National Institute on Alcohol Abuse and Alcoholism: Bethesda, MD; *http://alcoholpolicy.niaaa.nih.gov* (Accessed May 15, 2019).

143. O'Donnell MA: Research on drinking locations of alcohol-impaired drivers: Implications for prevention policies; *J Public Health Policy* 6:510; 1985.

144. O'Malley PM, Wagenaar AC: Effects of minimum drinking age laws on alcohol use, related behaviors and traffic crash involvement among American youth: 1976–1987; *J Stud Alcohol* 52:478; 1991.

145. Parker RN, Rebhun L: *Alcohol and Homicide: A Deadly Combination of Two American Traditions*; State University of New York Press: Albany, NY; 1995.

146. Preusser DF, Williams A, Nichols J, Tison J, Chaudhary N: *National Cooperative Highway Research Program: Effectiveness of Behavioral Highway Safety Countermeasures*; Transportation Research Board: Washington, DC; 2008.

147. Preusser DF, Williams AF, Zador PL, Blomberg RD: The effect of curfew laws on motor vehicle crashes; *Law Policy* 6:115; 1984.

148. Ramirez A, Berning A, Kelley-Baker T, Lacey JH, Yao J, Tippetts AS, Scherer M, Carr K, Pell K, Compton R: *2013–2014 National Roadside Study of Alcohol and Drug Use by Drivers: Alcohol Results* (Report No. DOT HS 812 362); US National Highway Traffic Safety Administration: Washington, DC; 2016.

149. Research and Evaluation Associates (REA): *The Effects Following the Implementation of an 0.08 BAC Limit and an Administrative per se Law in California*; US National Highway Traffic Safety Administration: Washington, DC; 1991.

150. Rogers P: *The General Deterrent Impact of California's 0.08% Blood Alcohol Concentration Limit and Administrative per se License Suspension Laws*; California Department of Motor Vehicles: Sacramento, CA; 1995.

151. Ross HL: Law, Science and Accidents: The British Road Safety Act of 1967; *J Legal Stud* 2:1; 1973.

152. Ross HL, Gonzales P: The effect of license revocation on drunk-driving offenders; *Accid Anal Prev* 20:379; 1988.

153. Royal D: *National Survey of Drinking and Driving: Attitudes and Behavior: 1999* (DOT HS 809 190 — Vol I: Findings); US National Highway Traffic Safety Administration: Washington, DC; 2000.

154. Runge J, Garrison H, Hall W, Waller A, Shen G: *Identification and Referral of Impaired Drivers Through Emergency Department Protocols*; US National Highway Traffic Safety Administration: Washington, DC; 2002; *http://www.nhtsa.dot.gov/people/injury/research/Idemergency/index.htm* (Accessed May 15, 2019).

155. SAE International: *Standard J3016 Titled Taxonomy and Definitions for Terms Related to On-Road Motor Vehicle Automated Driving Systems*; Society of Automotive Engineers: Warrendale, PA; 2014.

156. Sagberg F: Month-by-month changes in accident risk among novice drivers; *Proceedings — 14th International Congress of Applied Psychology*; Washington, DC; 1998.

157. Scherer M, Fell JC: Effectiveness of lowering the blood alcohol concentration (BAC) limit for driving from 0.10 to 0.08 grams per deciliter in the United States; *Traffic Inj Prev* 20:1; 2019.

158. Schermer CR, Moyers TB, Miller WR, Bloomfield LA: Trauma center brief interventions for alcohol disorders decrease subsequent driving under the influence arrests; *J Trauma* 60:29; 2006.

159. Sherman LW: Police Crackdowns: Initial and Residual Deterrence; *Crime and Justice — A Review of Research* (The University of Chicago Press Journal) 12:1; 1990.

160. Shope JT, Molnar LJ: Michigan's graduated driver licensing program: Evaluation of the first four years; *J Safety Res* 35:337; 2004.

161. Shope JT, Molnar LJ, Elliott MR, Waller PF: Graduated driver licensing in Michigan: Early impact on motor vehicle crashes among 16 year-old drivers; *JAMA* 286:1593; 2001.

162. Shults RA, Elder RW, Sleet DA, Nichols JL, Alao MO, Carande-Kulis VG, Zaza S, Sosin DM, Thompson RS: Task Force on Community Preventive Services: Reviews of evidence regarding interventions to reduce alcohol-impaired driving; *Am J Prev Med* 21(4 Suppl):66; 2001.

163. Smith DI: Effect on traffic safety of introducing a 0.05% blood alcohol level in Queensland, Australia; *Med Sci Law* 28:165; 1988.

164. Soderstrom CA, Dishinger PC, Kerns TJ, Kufera JA, Motchell KA, Scalea TM: Epidemic increases in cocaine and opiate use by trauma center patients. Documentation with a large clinical toxicology database; *J Trauma* 51:557; 2001.

165. Stewart K: *Alcohol Involvement in Fatal Crashes: Comparisons Among Countries*; US National Highway Traffic Safety Administration: Washington, DC; 2004.

166. Stoduto G, Mann R, Smart R, Adlaf E, Vingilis E, Beirness D, Lamble R: The impact of the administrative driver's Licence Suspension Law in Ontario; *15th International Conference on Alcohol, Drugs and Traffic Safety*; Stockholm, Sweden; May 22–26, 2000.

167. Subramanian R: *Transitioning to Multiple Imputation — A New Method to Estimate Missing Blood Alcohol Concentration (BAC) Values in FARS* (DOT HS 809 403); US National Highway Traffic Safety Administration: Washington, DC; 2002.

168. Swift RM: Direct measurement of alcohol and its metabolites; *Addiction* 98(Suppl 2):73; 2003.

169. Tauber J, Huddleston CW: *DUI/Drug Courts: Defining a National Strategy*; National Drug Court Institute: Alexandria, VA; 1999.

170. Teutsch SM, Naimi TS: Eliminating alcohol-impaired

driving fatalities: What can be done? *Ann Intern Med* 168:587; 2018.

171. Tison J, Solomon MG, Nichols J, Gilbert SH, Siegler JN, Cosgrove LA: *May 2006 Click It or Ticket Seat Belt Mobilization Evaluation*; US National Highway Traffic Safety Administration: Washington, DC; 2008.

172. Toomey TL, Rosenfeld C, Wagenaar AC: The minimum legal drinking age: History, effectiveness, and ongoing debate; *Alcohol Health Res World* 20:213; 1996.

173. Toomey TL, Wagenaar AC, Gehan JP, Kilian G, Murray DB, Perry CL: Project Arm: Alcohol risk management to prevent sales to underage and intoxicated patrons; *Health Educ Behav* 28:186; 2001.

174. Uber, Mother Against Drunk Driving: *More Options, Shifting Mindsets, Driving Better Choices*; 2015; *https://newsroom.uber.com/wp-content/uploads/2015/01/UberMADD-Report.pdf* (Accessed May 15, 2019).

175. Ulmer RG, Preusser DF, Williams AF, Ferguson SA, Farmer CM: Graduated licensing program on the crash rate of teenage drivers; *Accid Anal Preven* 32:527; 2000.

176. US Supreme Court: *Mackeay v. Montrym* 443 U.S. 1; 1979.

177. Vanlaar W, Mayhew D, Marcoux K, Wets G, Brijs Tom, Shope J: *An Evaluation of Graduated Driver Licensing Programs in North America*; Traffic Injury Research Foundation: Ottawa, Canada; 2009.

178. Voas RB: A new look at NHTSA's evaluation of the 1984 Charlottesville sobriety checkpoint program: Implications for current checkpoint issues; *Traffic Inj Prev* 9:22; 2008.

179. Voas RB: *Cars That Drunks Can't Drive*; US National Highway Safety Research Center: Washington, DC; 1969.

180. Voas RB: Monitoring drinking: Alternative to suspending license to control impaired drivers? *Transportation Research Record* (Journal of the Transportation Research Board) 2182:1; 2010.

181. Voas RB: Vehicle safety features for alcohol-related crashes; Personal communication; May 2019; Article to appear in the January 2020 issue of *Forensic Sci Rev*.

182. Voas RB, Fell JC: Preventing impaired driving: Opportunities and problems; *Alcohol Res Health* 34:225; 2011.

183. Voas RB, Fell JC: Programs and policies designed to reduce impaired driving; In Sher KJ (Ed): *The Oxford Handbook on Substance Use Disorders*, Vol 2; Oxford University Press: Oxford, UK; 2014.

184. Voas RB, Fell JC, Tippetts AS, Blackman K, Nichols J: Impact of primary safety belt laws on alcohol-related front-seat occupant fatalities: Five case studies; *Traffic Inj Prev* 8:232; 2007.

185. Voas RB, Hause JM: Deterring the drinking driver: The Stockton experience; *Accid Anal Prev* 19:81; 1987.

186. Voas RB, Holder HD, Gruenewald PJ: The effect of drinking and driving interventions on alcohol-involved traffic crashes within a comprehensive community trial; *Addiction* 92(Suppl 2):S221; 1997.

187. Voas RB, Lacey JC: *Alcohol and Highway Safety 2006: A Review of the State of Knowledge* (DOT HS 811-374); US National Highway Traffic Safety Administration: Washington, DC; 2011; *https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/811374.pdf* (Accessed May 15, 2019).

188. Voas RB, Rhodenizer AE, Lynn C: *Evaluation of Charlottesville Checkpoint Operations*; US National Highway Traffic Safety Administration: Washington, DC; 1985.

189. Voas RB, Romano E, Peck R: Validity of the passive sensor for identifying high BAC drivers at the crash scene; *J Stud Alcohol* 67:714; 2006.

190. Voas RB, Taylor EP, Kelley-Baker T, Tippetts AS: *Effectiveness of the Illinois .08 Law*; US National Highway Traffic Safety Administration: Washington, DC; 2000.

191. Voas RB, Tippetts AS, Fell J: Assessing the effectiveness of minimum legal drinking age and zero tolerance laws in the United States; *Accid Anal Prev* 35:579; 2003.

192. Voas RB, Tippetts AS, Fell JC: The relationship of alcohol safety laws to drinking drivers in fatal crashes; *Accid Anal Prev* 32:483; 2000.

193. Voas RB, Torres P, Romano E, Lacey JH: Alcohol-related risk of driver fatalities: An update using 2007 data; *J Stud Alcohol Drugs* 73:341; 2012.

194. Wagenaar AC: Raising the legal drinking age in Maine: Impact on traffic accidents among young drivers; *Inter J Addict* 18:365; 1983.

195. Wagenaar AC: The minimum legal drinking age: A time-series impact evaluation; *Dissertation Abstracts International* 41(8B):2984; 1981.

196. Wagenaar AC, Maldonado-Molina MM: Effects of drivers' license suspension policies on alcohol-related crash involvement: Long-term follow-up in forty-six States; *Alcohol Clin Exp Res* 31:1399; 2007.

197. Wagenaar AC, Maldonado-Molina MM, Ma L, Tobler A, Komro K: Effects of legal BAC limits on fatal crash involvement: Analyses of 28 states from 1976 through 2002; *J Safety Res* 38:493; 2007.

198. Wagenaar AC, Toomey TL: Effects of minimum drinking age laws: Review and analyses of the literature from 1960 to 2000; *J Stud Alcohol* (Suppl 14):206; 2002.

199. Wagenaar AC, Zobeck TS, Hingson R, Williams GD: Studies of control efforts: A meta-analysis from 1960 through 1991; *Accid Anal Prev* 27:1; 1995.

200. Wells JK, Preusser DF, Williams AF: Enforcing alcohol-impaired driving and seat belt use laws, Binghamton, New York; *J Safety Res* 23:63; 1992.

201. Wilde CJS, Hoste JL, Sheppard D, Wind G: *Road Safety Campaigns: Design and Evaluation*; Organization for Economic Co-Operation and Development: Paris, France; 75 pp; 1971.

202. Williams A: 1980's decline in alcohol impaired driving and crashes and why it happened; *Alcohol Drugs Driving* 8:71; 1992.

203. Williams AF: Young driver accidents: In search of solutions; In Mayhew DR, Simpson HM, Donalsen AC (Eds): *Laws and Regulations Applicable to Teenagers or New Drivers: Their Potential for Reducing Motor Vehicle Injuries*; The Traffic Injury Research Foundation: Ottawa, Canada; p 43; 1985.

204. Williams AF, Rich RF, Zador PI: The legal minimum drinking age and fatal motor vehicle crashes; *J Legal Stud* 12:169: 1975.

205. Williams AF, Zador PL, Harris SS, Karpf RS: The effect of raising the legal minimum drinking age on involvement in fatal crashes; *J Legal Stud* 12:169; 1983.

206. Williams AK, Weinberg K, Fields M: Effectiveness of administrative license suspension laws; *Alcohol Drugs Driving* 7:55; 1991.

207. Wiliszoski C, Jones R, Lacey J: *Examining the Effectiveness of Utah's Law Allowing Telephonic Testimony at ALR*

Hearings (DOT HS 809 602); US National Highway Traffic Safety Administration: Washington, DC; 2003.

208. Womble K: Impact of minimum drinking age laws on fatal crash involvements: An update of the NHTSA analysis; *J Traffic Safety Educ* 37:4; 1989.

209. World Health Organization (WHO): *Global Status Report on Road Safety*; WHO: Geneva, Switzerland; 2018.

210. World Health Organization (WHO): *List of Countries' BAC Limits for Driving; World Health Organization*; Geneva, Switzerland; 2013; *http://apps.who.int/gho/athena/data/ GHO/SA_0000001520.html?profile=ztable&filter=COU NTRY:*;BACGROUP:** (Accessed May 15, 2019).

211. Wurst FM, Vogel R, Jachau K, Varga A, Alling C, Alt A, Skipper GE: Ethyl glucuronide discloses recent covert alcohol use not detected by standard testing in forensic psychiatric inpatients; *Alcohol Clin Exp Res* 27:471; 2003.

212. Zador P, Krawchuck S, Moore B: *Drinking and Driving Trips, Stops by Police, and Arrests: Analyses of the 1995 National Survey of Drinking and Driving Attitudes and Behavior* (DOT HS 809 184); US National Highway Traffic Safety Administration: Washington, DC; 2000.

213. Zador PL, Krawchuk SA, Voas RB: Alcohol-related relative risk of driver fatalities and driver involvement in fatal crashes in relation to driver age and gender: An update using 1996 data; *J Stud Alcohol* 61:387; 2000.

214. Zador PL, Lund AK, Field M, Weinberg K: *Alcohol-Impaired Driving Laws and Fatal Crash Involvement*; Insurance Institute for Highway Safety: Washington, DC; 1988.

215. Zaloshnja E, Miller T, Blincoe L: Costs of alcohol-involved crashes, United States, 2010; *Ann Adv Automot Med* 57:3; 2013.

216. Zwerling C, Jones MP: Evaluation of the effectiveness of low blood alcohol concentration laws for younger drivers; *Am J Prev Med* 16(1 Suppl):76; 1999.

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From 2001 to 2015 Mr. Fell was a senior research scientist at the Pacific Institute for Research & Evaluation (PIRE) in Calverton, MD. Before that, he worked at the US National Highway Traffic Safety Administration (NHTSA) in Washington, DC, from 1969 to 1999. While at NORC, Mr. Fell has completed a survey of highway safety issues for the New Mexico Highway Safety Office, an evaluation of a special DUI enforcement program for the Maryland Highway Safety Office, and a comprehensive analysis of DUI in crashes, roadside surveys, and arrests in Miami-Dade County for the Miami Foundation. For the Insurance Institute for Highway Safety (IIHS) he recently evaluated all alcohol ignition interlock laws in the US for their effectiveness and currently is studying the enforcement of minimum marijuana use age 21 laws in California. He has completed research on the effectiveness of graduated driver-licensing laws under a grant from the National Institute of Child Health and Human Development (NICHHD), on enforcement intensity measures and impaired driving on the roads, the effectiveness of underage alcohol policies, and the potential effectiveness of lowering the BAC limit from .08 to .05 BAC for driving sponsored by the National Institute on Alcohol Abuse and Alcoholism (NIAAA), and studies on the effectiveness of responsible beverage-service training and enforcement, alcohol ignition interlock laws, high-visibility enforcement, and alcohol-monitoring devices on impaired-driving offenders for NHTSA. He has over 50 years of traffic safety and alcohol policy research experience and has authored or coauthored over 165 publications in book chapters, scientific journals, and conference proceedings.

Mr. Fell is a longtime member of the Association for the Advancement of Automotive Medicine (AAAM) (since 1969), including as past president (1988), Board of Directors member (1974–76, 1982–84, 2009–2011), scientific program chairman (1976), membership chairman (1981), treasurer (1985–86); fellow (1994); three-time Best Scientific Paper award winner (1979, 1983, and 2010); and recipient in 2016 of the Donald F. Huelke Lifetime Membership Award. Mr. Fell is currently president-elect of and the 2013 recipient of the Widmark Award from the International Council on Alcohol, Drugs, and Traffic Safety (ICADTS), and a member of the Research Society on Alcoholism (RSA), the Society for Prevention Research (SPR), and the Human Factors and Ergonomics Society (HFES). In 2015, Mr. Fell received the James J. Howard Highway Safety Trailblazer Award from the Governors' Highway Safety Association (GHSA) for sustained outstanding leadership in endeavors that significantly improve highway safety, and the Kevin Quinlan Advocacy Award from the Maryland Highway Safety Office.