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Estimation of the Potential Effectiveness of Lowering the Blood Alcohol Concentration (BAC) Limit for Driving from 0.08 to 0.05 Grams per Deciliter in the United States

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Background: In 2013, the National Transportation Safety Board (NTSB) issued a report recommending that states lower the illegal blood alcohol concentration (BAC) limit for driving from 0.08 to 0.05 g/dl. The NTSB concluded that there is a strong evidence-based foundation for a BAC limit of 0.05 or lower. Most industrialized nations have already enacted a 0.05 illegal BAC limit. This study was undertaken to contribute to the scientific evidence as to whether lowering the BAC limit to 0.05 will be an effective alcohol policy in the United States.

Methods: We accomplished our objective by: (i) conducting a meta-analysis of qualifying international studies to estimate the range and distribution of the most likely effect size from a reduction to 0.05 BAC or lower; (ii) translating this synthesis toward estimating the effects of reducing the current 0.08 BAC limit to 0.05 in the United States; and (iii) estimating the life-saving benefits of the proposed 0.03 reduction in the driving limit from 0.08 to 0.05 BAC.

Results: In our meta-analysis of studies on lowering the BAC limit in general, we found a 5.0% decline in nonfatal alcohol-related crashes, a 9.2% decline in fatal alcohol-related crashes from lowering the BAC to 0.08, and an 11.1% decline in fatal alcohol-related crashes from lowering the BAC to 0.05 or lower. We estimate that 1,790 lives would be saved each year if all states adopted a 0.05 BAC limit.

Conclusions: This study provides strong evidence of the relationship between lowering the BAC limit for driving and the general deterrent effect on alcohol-related crashes.

Key Words: Effectiveness, BAC Limit, 0.05 g/dl, Meta-Analysis, Lives Saved.

IN EVERY STATE in the United States, it is illegal per se (i.e., no other evidence needed) for adults to drive with a blood alcohol concentration (BAC) of 0.08 g/dl or greater, for drivers younger than 21 years to drive with any positive alcohol concentration (BAC $\geq$ 0.02), and for commercial drivers (e.g., trucks, buses, taxis) to drive with a BAC of 0.04 g/dl or greater. An analysis by Tippetts and colleagues (2005) found a significant decline of 14.8% in the rate of drinking drivers in fatal crashes after 0.08 laws were introduced in 18 states and the District of Columbia (DC). An earlier study by Voas and colleagues (2000) found an 8% reduction in drinking drivers in fatal crashes associated with lowering the BAC limit to 0.08. Numerous other studies have confirmed these findings (Bernat et al., 2004; Dee, 2001; Eisenberg, 2001; Hingson et al., 2000; Shults et al., 2001). The adoption of so-called zero tolerance laws for drivers under the age of 21 has also been shown to be effective (Blomberg, 1992; Hingson et al., 1994).

In 1986, when the U.S. Department of Transportation (DOT) took its first formal step toward advocating for the illegal BAC limit to be lowered from 0.10 to 0.08, only 2 states had enacted such laws: Oregon and Utah in 1983. That federal government's initiative involved a regulatory action specifying the enactment of a 0.08 law as a criterion for a supplemental alcohol traffic safety grant under a program authorized by the U.S. Congress (23 U.S.C. 408). Consequently, additional states began to consider 0.08 BAC per se levels, and 3 more states adopted the new level: Maine in 1988, California in 1990, and Vermont in 1991. Between 1992 and 1998, 10 additional states in the United States adopted 0.08 BAC per se laws. The movement toward a national standard for 0.08 BAC received renewed attention in the 105th Congress. On June 15, 2000, the U.S. Senate passed H.R. 4475 (the DOT Appropriations Bill for FY 2001), which included a general provision encouraging states to adopt 0.08 BAC laws by withholding a portion of a state's federal highway construction funds, beginning in FY 2004, for states that did not adopt the 0.08 limit. Congress adopted the final 0.08 BAC bill (Section 351) in 2000, and the President signed the law shortly thereafter. This federal legislation technically expired on September 30, 2013, but has been renewed by Congress each year since then.

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Since the federal 0.08 BAC legislation was passed, a number of evaluation studies have been conducted. For example, Wagenaar and colleagues (2007) found direct effects of lowering the BAC limits in 28 states and estimated that 360 deaths were prevented by the 0.08 BAC law and that an additional 538 lives could be saved if the United States lowered its BAC limit to 0.05 BAC. Gorman and colleagues (2006), on the other hand, could not find any significant effects on alcohol-related crashes or fatalities due to the 0.08 BAC law in Texas. It has been 12 years since the last state adopted a 0.08 BAC law (Minnesota in 2005) and 34 years since the first state adopted a 0.08 BAC law (Utah in 1983).

Significance of this Study

Laws adopted in the United States to control and reduce alcohol-impaired driving vary considerably between states (National Highway Traffic Safety Administration, 2016). These laws have been adopted over the past 100 years and form the legal structure that enables law enforcement to stop drivers on public roads (with reasonable suspicion) and arrest them for driving while intoxicated (DWI) (with probable cause). Criminal sanctions for a first-offense DWI conviction typically consist of at least a driver's license suspension or revocation period decided by the judge; a fine; some alcohol education or intervention; and either some time in jail, some period under house arrest, or some minimal hours of community service. Currently, 41 states and DC have Administrative License Revocation (ALR) laws, which provide that the license of a driver with a BAC at or over the illegal 0.08 g/dl BAC limit is subject to an immediate driver's license suspension by the state department of motor vehicles. ALR laws are the most widely applied example of a traffic law where the sanction rapidly follows the offense. The power of ALR laws has generally been attributed to how swiftly and how consistently the sanction is applied (Shults et al., 2001; Voas et al., 2000).

Between 1982 and 1997, the key modern impaired driving laws were adopted by most of the 50 states and DC (Fell and Voas, 2006). As a result, there was a substantial decrease in the proportion of traffic fatalities involving alcohol-impaired drivers during that period. In 1982, 35% of drivers involved in fatal crashes had illegal BACs (≥0.08 g/dl). That dropped to 20% by 1997. Since 1997, however, progress has stalled and the percentage of drivers with illegal BACs has remained at about 21% (Dang, 2008; Fell et al., 2009).

On May 14, 2013, the National Transportation Safety Board (NTSB), an independent federal agency dedicated to promoting transportation safety, issued a report recommending, among other measures, that states lower the illegal BAC limit for driving from 0.08 to 0.05 g/dl (National Transportation Safety Board, 2013). Most industrialized nations have already enacted a 0.05 illegal BAC limit (World Health Organization, 2013). However, there was a lack of enthusiastic support from some organizations, such as Mothers Against Drunk Driving, who questioned the potential benefit of a 0.05 BAC law. The National Highway Traffic Safety Administration (NHTSA) of the U.S. DOT did not formally support the recommendation either. Officials at NHTSA have stated, however, that states are free to lower their illegal BAC limit to 0.05 or lower if they feel that is appropriate and NHTSA will evaluate the effects (Michael, 2014). The National Safety Council has recommended a 0.08 BAC limit but issued a policy statement that would recommend lowering that limit to 0.05 g/dl BAC or lower (http://www.nsc.org/DistractedDrivingDocuments/Low-BAC-policy.pdf). On the other hand, in 1997, the American Medical Association recommended that the limit for driving should be 0.05 BAC. This lack of full support raises the issue as to whether enactment of a law reducing the illegal BAC limit for driving to 0.05 will be an effective strategy in the United States. This study should contribute significantly to the scientific evidence, either way, as to whether lowering the BAC limit to 0.05 will be an effective alcohol policy.

Current Research

Numerous independent studies in the United States indicate that lowering the illegal BAC limit from 0.10 (adopted by states in the 1960s and 1970s) to 0.08 (adopted by states between 1983 and 2005) has resulted in 5 to 16% reductions in alcohol-related crashes, fatalities, or injuries (Bernat et al., 2004; Dee, 2001; Eisenberg, 2001; Hingson et al., 2000; Shults et al., 2001; Voas et al., 2000). The illegal limit is 0.05 BAC in many countries around the world, and several international studies indicate that lowering the illegal per se limit from 0.08 to 0.05 BAC reduces alcohol-related fatalities (Bartl and Esberger, 2000; Brooks and Zaal, 1993; Homel, 1994). Laboratory studies indicate that impairment in critical driving functions begins at low BACs and that most subjects are significantly impaired at 0.05 BAC (Ferrara et al., 1994; Martin et al., 2013; Moskowitz et al., 2000). The relative risk of being involved in a fatal crash as a driver is 4 to 6 times greater for drivers with BACs between 0.05 and 0.07 compared to drivers with 0.00 BACs (Voas et al., 2012). The extant literature has shown the efficacy of lowering the BAC limit: (i) from 0.10 to 0.08, (ii) from 0.08 to 0.05, (iii) from 0.05 to 0.03 or 0.02, and (iv) for youth to any measurable amount of alcohol (zero tolerance laws). These law changes apparently serve as a general deterrent to drinking and driving. A recent survey of a nationally representative sample of drivers aged 18 years and older in the United States indicated that 63.6% support lowering the per se BAC limit from 0.08 to 0.05 (Arnold and Teftt, 2016).

This study provides a foundation for considering a reduction in the BAC limit to 0.05 by conducting a meta-analysis of studies that examined the impact of lowering the illegal BAC limit to 0.05 in foreign countries in order to estimate the effect of lowering the BAC limit from 0.08 to 0.05 in the United States.

MATERIALS AND METHODS

Objectives

The specific objective of our study was to *estimate the potential effectiveness of reducing the illegal BAC limit for driving from 0.08 to 0.05 g/dl in the United States*. We accomplished this objective by: (i) conducting a meta-analysis of qualifying international studies to estimate the range and distribution of the most likely effect size from a reduction to a 0.05 BAC limit or lower; (ii) translating this synthesis toward estimating the potential benefits in the United States of reducing the current BAC limit from 0.08 to 0.05; and (iii) analyzing the life-saving benefits of the proposed 0.03 reduction in the illegal limit from 0.08 to 0.05 BAC. As effects of BAC limits on alcohol consumption measures are important to the hospitality industry and, perhaps, the economy, we included alcohol consumption measures in our analyses.

Study Description

Our study sought to examine the literature on the effects of lowering the BAC limit and the impact of doing so on adverse driving outcomes (i.e., drinking and driving, and fatal and nonfatal alcohol-related traffic crashes). Although all studies that examined the impact of changing BAC limits were considered, the current study is organized into 2 primary sections. The first deals with lowering the BAC limit to 0.08 (generally from 0.10), and the second deals with lowering the BAC to 0.05 or lower.

To achieve this goal, we conducted extensive literature reviews using a series of databases that provided access to scholarly published literature including E-Journals, MEDLINE, PsycArticles, PsycInfo, and PUBMED. Using keywords relevant to the current endeavor (i.e., BAC, fatal crashes, 0.08 BAC, 0.05 BAC, reduce BAC), these searches produced 421 articles (see Fig. 1 for a flow diagram). Of those articles, 320 were found not to contain studies examining the change in BAC laws. Of the remaining articles, 80 did not provide sufficient data to allow for inclusion in the meta-analysis conducted in the current study. This list of articles was then refined to include only empirical articles examining outcomes of changing BAC laws and which presented data sufficient (i.e., effect sizes) for inclusion in the current study. This resulted in 21 total articles. These articles were then carefully reviewed and references examined for further articles that may not have been uncovered by the literature searches. Any additional articles uncovered were then reviewed and references examined in a similar fashion and so on. This was continued until only articles already included in the extant database were uncovered. For the current study, only empirical journal articles were considered. As conference findings are not peer-reviewed and validated, they were only included in the current study if they were later converted to an empirically reviewed journal article. Government reports, however, were included unless the report was later converted into a journal article. In those cases, only the journal article was included in the current study. In the end, this enhanced search yielded a total of 37 articles for use in the analysis.

Study Design

For this first study, we collected 37 empirical articles. However, as each study examined the effects of BAC changes differently, it was necessary to first standardize studies for comparison across groups. To do this, we first calculated Hedges G (d_G) (Durlak, 2009; Hedges, 1981) for each study representing standardized differences (i.e., the change in adverse driving-related outcomes pre- and post-BAC change) using the formula below, where X represents the population means/percentages, S^2 represents variance, n represents group sample size, and N represents total sample size. Values with the subscript 1 indicate values prior to the treatment (i.e., BAC limit change), while the subscript 2 indicates values following the introduction of the treatment.

$$d_G = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{(n_1 - 1)S_1^2 + (n_2 - 1)S_2^2\ N - 2}}.$$

As shown in the formula, Hedges G is a more useful representation of the difference than Cohen's d, as the denominator represents the pooled variance. For studies that present multiple findings (i.e., a percentage change for each jurisdiction studied), the overall change statistic is used. Note that change values were always rounded to the nearest whole number.

Dependent Measures

Each of the studies examined in the current endeavor provided data regarding the effect of lowering the BAC limit either from 0.08 to 0.05 g/dl, or to 0.03 or lower. Several studies varied in terms of what outcome they were looking at and how that outcome was specifically measured. In our review, we found that 25 studies used fatal alcohol-related crashes as the outcome measure. Of these, 14

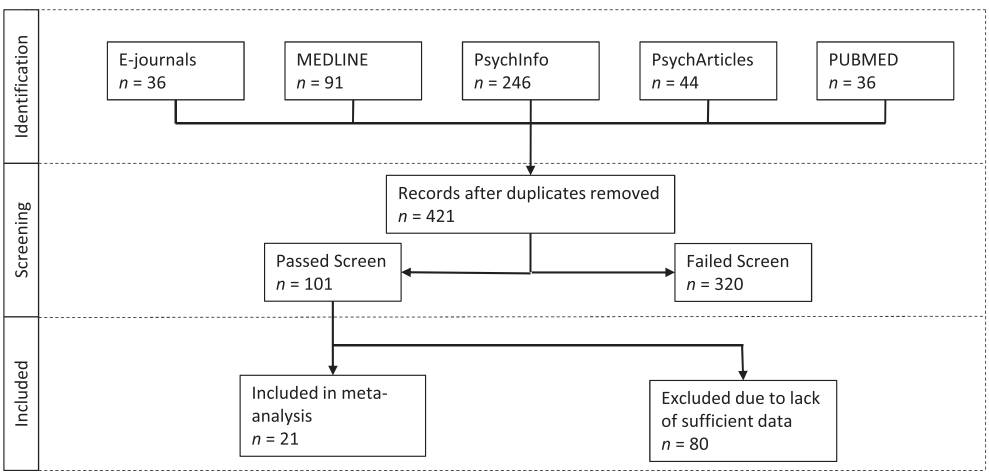

Fig. 1. Study selection flow diagram.

examined the effects of reducing BAC limits from 0.10 to 0.08 g/dl, while 11 examined reducing BAC limits to 0.05 g/dl or below. Further, 9 studies examined the impact of changing BAC laws primarily on nonfatal alcohol-related crashes, while 6 others simply examined whether drivers had been drinking either by self-report or by biological measurement. As each of these outcomes is relevant to the current study, each outcome type (i.e., alcohol consumption, fatal and nonfatal crashes) was considered in the analysis.

Analysis

To analyze the cross-study impact of lowering the BAC limit, we conducted a series of meta-analyses. Meta-analysis is a common statistical methodology used to synthesize research findings from conceptually similar studies with the goal of drawing out a common conclusion (Lipsey and Wilson, 2001). A particular strength of meta-analysis is the aggregation of data to improve statistical power and, hence, derive more meaningful conclusions. Using the aggregate of effect sizes also allows researchers to synthesize multiple studies and avoid pitfalls where studies with significant findings weigh more to the outcome than studies that report an effect size, but not one that meets statistically significant criteria. Further, a particular strength of meta-analytic techniques is that they allow for the inclusion of multiple studies despite the findings of individual studies. That is, even in the event that a study failed to find a significant effect of a change in alcohol-related crashes or outcomes following lowering of BAC limits, it was still included in the final analysis of the current study.

RESULTS

Our current analysis identified 6 studies examining how reducing BAC limits impacts alcohol-related variables (Table 1; Fig. 2). Two of those studies demonstrated modest decreases in self-reported alcohol consumption (Campos et al., 2013) and the number of drinks consumed before feeling drunk (Kerr et al., 2006). The 4 other studies found that lowering the BAC limit had no significant effect on alcohol-related outcomes (Apsler et al. 1999; Bernhoft and Behrensdorff, 2003; Noordzij, 1994; Schwartz and Davaran, 2013). Interestingly, the 3 studies that found a negative relationship between law implementation and alcohol-related variables (2 of which were significant) relied primarily on self-report in their methods; however, this finding was not supported by studies relying primarily on biological data collection. This may indicate a difference in drivers' thoughts versus their behaviors. That is, lowering the BAC limit may begin to influence drivers' thoughts toward drinking and driving (which would be reflected in their self-reported responses), but behavioral change in these cases may be slow to follow.

Table 2 and Fig. 3 summarize 9 studies that assessed the impact of lowering the illegal BAC limit to 0.08 or below and the impact on nonfatal alcohol-related crashes. With the exception of the study by Maisey (1984), all studies found a significant decrease in nonfatal alcohol-related crashes following the reduction in BAC limit. Of those studies, only the studies by Kaplan and Prato (2007) and Wagenaar and colleagues (2007) examined the impact of reducing the BAC limit to 0.08 from 0.10, while the remaining 6 studies examined the impact of lowering the BAC limit to 0.05 or further.

Table 1. Mean Change in Alcohol Use Among Studies Evaluating a Reduction in the Illegal BAC Limit

Article	Location/time span	Outcome measure	Analysis used	Results	Change value
Apsler and colleagues (1999)	United States 1982 to 1994	Fatal crash rates in FARS	Time-series analysis (ARIMA)	Although results varied notably between states, only marginal differences were found in alcohol consumption rates following law implementation. The increase was not significant	NS
Bernhoft and Behrensdorff (2003)	Denmark 1993 to 1999	Self-reported drinking and driving, alcohol-related injury accidents	Chi-square and independent-samples *t*-test	Drivers reported drinking less alcohol following law implementation. Findings were not statistically significant	NS
Campos and colleagues (2013)	Brazil 2007 to 2009	Rates of drinking and driving	Logistic regression analysis	Following the implementation of the law, there was a significant decrease in positive breath tests and self-reported rates of alcohol consumption	−2
Kerr and colleagues (2006)	United States 1979, 1995, and 2000	Perception of drunkenness	Trend analysis using 3 cross-sectional surveys	Mean number of reported drinks to feel drunk declined significantly following law implementation for men (but not for women)	−1
Noordzij (1994)	Netherlands 1983 and 1992	Alcohol use among roadside surveys	Observation of trend	Drivers who screened positive for alcohol decreased following the law implementation	NS
Schwartz and Davaran (2013)	United States (24 jurisdictions) 1990 to 2007	Alcohol-related driving and arrests among gender	Two-way fixed-effects regression models	Alcohol-related arrests increased for both genders (though women in particular) after law implementation. Change was not statistically significant	NS

ARIMA, autoregressive integrated moving average; FARS, fatality analysis reporting system.

Article	Mean	SD	95% CI lower	95% CI upper
Aspler et al., 1999	0.031	0.047	-0.016	0.078
Bernhoft & Behrensdorff, 2003	-0.018	0.031	-0.049	0.013
Campos et al., 2013	-0.023	0.007	-0.03	-0.016
Kerr et al., 2006	-0.011	0.004	-0.015	-0.007
Noordzij, 1994	-0.051	0.083	-0.134	0.032
Schwartz & Davaran, 2013	0.031	0.061	-0.03	0.092

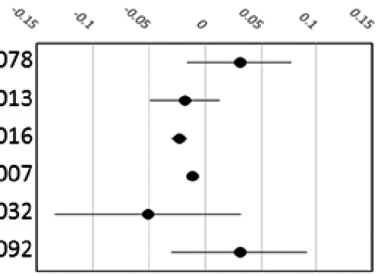

Fig. 2. Mean change in alcohol consumption outcomes after lowering of BAC limits.

Table 2. Mean Change in Nonfatal Crashes Among Studies Evaluating a Reduction in the Illegal BAC Limit

Article	Location/time span	Outcome measure	Analysis used	Results	Change value
Blomberg (1992)	United States (Maryland) 1989 to 1990	Crash rates of drivers under age of 21 who had been drinking	Box-Jenkins time-series analysis	Reduction of underage sanctions to 0.02. Implementing this law resulted in significant decreases in rates in which crash-involved underage drivers were found to have been drinking	−11
Brooks and Zaal (1993)	Australia 1991 and 1992	Drinking and driving and alcohol-related crashes	Chi-square and independent-samples *t*-test	Following the law implementation, a significant decrease was noted in BACs of drivers on the road	−6
Desapriya and colleagues (2007)	Japan 1998 to 2005	Alcohol-related crashes among male and female drivers	Logistic regression analysis	Introduction of reduced BAC limit resulted in significant decreases in alcohol-impaired drivers on the road and alcohol-related crashes	−4
Gorman and colleagues (2006)	United States (Texas) 1995 to 2002	Fatal crash rates in FARS and TX Department of Public Safety reports on alcohol-related crashes	Time-series analysis (ARIMA)	Separate ARIMA analysis was conducted for both outcome measures with no significant outcome detected	NS
Haque and Cameron (1989)	Australia (Victoria) 1984 to 1995	Rates of serious traffic crashes	Pre- to postcomparison	Reduction in BAC limits resulted in mild nonsignificant decreases in alcohol-related driving and crashes	−4
Kaplan and Prato (2007)	United States (22 jurisdictions) 1990 to 2005	Alcohol-related single-vehicle crashes and law effects on population segments	Poisson regression models	Reduction in BAC limit resulted in reduced numbers of casualties among single-vehicle crashes. Female and elderly drivers were more adherent to new law requirements when compared to younger drivers and male drivers	−8
Karakus and colleagues (2015)	Turkey 2010 and 2011	Nonfatal crashes among private sector and public transportation vehicles	Chi-square and independent-samples *t*-test	Private sector drivers (who have a BAC limit of 0.05) were significantly more likely than public transportation sector drivers (who have a BAC limit of 0.00) to be involved in a nonfatal crash following reduction in BAC	−2
Maisey (1984)	Australia (Western Australia) 1981 to 1983	Alcohol use among drivers and alcohol-related crashes	Pre- to postcomparison	Reduction in BAC limits resulted in mild decreases in reported alcohol-related driving and rates of alcohol-related crashes	NS
Wagenaar and colleagues (2007)	United States (28 jurisdictions) 1976 to 2002	Single nighttime vehicle crashes and alcohol-related crashes	Time-series analysis (ARIMA)	Due to considerable state-by-state variability, individual effects could not be deduced; however, pooled analysis demonstrated that changes in BAC law resulted in significant reductions in both single nighttime vehicle crashes and alcohol-related crashes	−6

ARIMA, autoregressive integrated moving average; FARS, fatality analysis reporting system.

Interestingly, the study by Blomberg (1992) found the most significant effect of lowering BAC limits pre- and post-law implementation. This may be due in part to the nature of the study conducted. That is, the study examined the impact of lowering BAC levels to 0.02 among underage drivers, while the other studies tended to examine drivers who were 21 years and older. This may be relevant because underage drinking in the United States has decreased substantially

Article	Mean	SD	95% CI lower	95% CI upper
Blomberg, 1992	-0.114	0.036	-0.15	-0.078
Brooks & Zaal, 1993	-0.059	0.037	-0.096	-0.022
Desapriya et al., 2007	-0.036	0.022	-0.058	-0.014
Gorman et al., 2006	-0.004	0.028	-0.032	0.024
Haque & Cameron, 1989	-0.043	0.028	-0.071	-0.015
Kaplan & Prato, 2007	-0.077	0.03	-0.107	-0.047
Karakus et al., 2015	-0.021	0.019	-0.04	-0.002
Maisey, 1984	-0.036	0.021	-0.057	-0.015
Wagenaar et al., 2007	-0.058	0.041	-0.099	-0.017

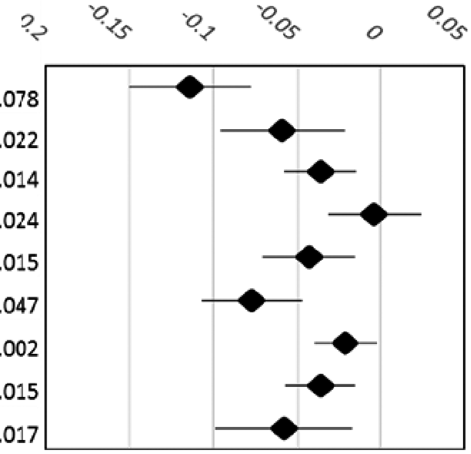

Fig. 3. Mean change in nonfatal alcohol-related crash rates after lowering of BAC limit to 0.08.

since the minimum legal drinking age of 21 was established in 1984 (Fell et al., 2016; Johnston et al., 2009; O'Malley and Wagenaar, 1991).

Studies that examined the impact of implementing legislation reducing the BAC limit from 0.10 to 0.08 g/dl show considerable variation between studies with effect sizes ranging from no effect to an 18% reduction in fatal crashes (Table 3; Fig. 4). Interestingly, 5 of the 14 studies examined in the current research did not find a significant impact of reducing the BAC limit to 0.08. Although they do note a decrease in fatal alcohol-related crashes following law implementation, it was not found to be statistically significant. Two primary reasons are presented to explain this lack of significance. First, some studies suggest that it is the frequent simultaneous implementation of other alcohol-related legislation, such as ALR laws, that explained most of the variance in the United States (Research and Evaluation Associates [REA], 1991). That is, although lowering the BAC limit may help in the reduction in fatal crashes, its simultaneous implementation with other more effective legislation may have inflated its relevance in studies that did not control for this. Second, some studies suggested that the decrease in fatal crash rates can be better explained by the natural declining trend of fatal crashes around the world rather than the implementation of a law (Foss et al., 2001). This, however, is in contrast to the study by Nagata and colleagues (2008), which controlled for natural trends and still found a notable impact of legislation limiting BAC levels.

Table 4 and Fig. 5 show a summary of research examining the impact of implementing legislation reducing the illegal BAC limit (i) from 0.08 to 0.05, (ii) from 0.05 to 0.03, or (iii) from 0.05 to 0.02. Of particular note is the Nagata and colleagues (2008) study, which found a 38% reduction effect on fatal crashes after legislation was implemented reducing the BAC limit to 0.03. Although clearly relevant to the current study, and hence retained for analysis, this study could represent an outlier. Despite this, however, the studies by Andreuccetti and colleagues (2011), Nagata and colleagues (2008), Norström (1997), and Smith (1986) showed a significant decrease in fatal alcohol-related crashes when the illegal BAC limit was lowered to below 0.05. The other studies that looked at reducing the BAC limit lower than 0.05 found no significant impact on fatal crash rates (Assum, 2010; Nakahara et al., 2013; Živković et al., 2013). Similarly, 3 of the 4 studies examining the impact of lowering the illegal BAC limit to 0.05 found significant decreases in alcohol-related fatal crashes after law implementation (Henstridge et al., 1997; Hingson et al., 1998; Homel, 1994), while 1 did not (McLean et al., 1995). Importantly, McLean and colleagues (1995) note that the change in the law for the Australian illegal BAC limit did indeed reduce the number of fatal alcohol-related crashes, but the effects were both relatively mild and short-lived. As time passed after law implementation, the benefits of the law dissipated.

Table 5 shows the results of the meta-analysis. Results are presented after weighting for sample sizes in each study and comparing percentage reductions in outcomes. Results are drawn from change values for each study listed in Tables 1–4. In the event that a study found no significant (NS) effect of the law change, the effect size reported in the study was still included in the overall estimated impact.

Variables Related to Alcohol Use

Although 2 of the 6 studies examining variables related to alcohol use (Table 5, Row 1) did indeed find a significant impact on alcohol use outcomes of lowering BAC laws, these studies had only a mild effect size. Further, although all studies in this group were indeed alcohol-related outcomes, the specific outcome measures varied notably between studies making comparisons difficult.

Nonfatal Alcohol-Related Crashes

Ideally, studies would be categorized by the extent to which the BAC limit was reduced (i.e., from 0.10 to 0.08,

Table 3. Mean Change in Fatal Alcohol-Related Crashes Among Studies Evaluating a Reduction of the Illegal BAC Limit from 0.10 to 0.08 g/dl

Article	Location/time span	Outcome measure	Analysis used	Results	Change value
Apsler and colleagues (1999)	United States 1982 to 1994	Fatal crash rates in FARS	Time-series analysis (ARIMA)	Although results varied notably between states, overall few states demonstrated marginal differences between law implementation and fatal crash rates and/or alcohol consumption rates. In a few cases, there appeared to be an increase in alcohol consumption and law implementation, although not significant	NS
Asbridge and colleagues (2015)	Canada 1962 to 1996	Fatally injured drinking drivers and fatally injured nondrinking drivers	Time-series analysis (ARIMA)	There was a significant reduction in the number of fatally injured drinking drivers, but no detectable impact on nondrinking driver fatalities	−18
Bernat and colleagues (2004)	United States (19 jurisdictions) 36 months before and after 0.08 law implementation	Fatal crash rates in FARS	Mixed-model Poisson regression analysis	Significant decreases in fatal crashes found in 3 of 19 states	−5
Bernhoft and Behrensdorff (2003)	Denmark 1993 to 1999	Self-reported drinking and driving, alcohol-related injury accidents	Chi-square and independent-samples *t*-test	Rates of fatal alcohol-related crashes increased following law implementation. Findings were not statistically significant	NS
Dee (2001)	United States 1982 to 1998	Fatal crash rates	Panel-based analysis	Following the adoption of the 0.08 BAC law, traffic fatalities were reduced by 7.2% in the 14 states that adopted them	−7
Foss and colleagues (2001)	United States (North Carolina) 1991 to 1996	Fatal crash rates in FARS	Trend analysis	After accounting for the downward trend of fatal crashes, no significant effect was found due to law implementation	NS
Gorman and colleagues (2006)	United States (Texas) 1995 to 2002	Fatal crash rates in FARS and TX Department of Public Safety reports on alcohol-related crashes	Time-series analysis (ARIMA)	Separate ARIMA analysis was conducted for both outcome measures with no significant outcome detected	NS
Hingson and colleagues (1994)	United States (12 jurisdictions) Varied with each of 12 states examined	Fatal single-vehicle nighttime crashes among drivers under age of 21	Log-linear analysis	Proportion of fatal single-vehicle nighttime crashes among young drivers decreased by 22% in states with 0.00 BAC limits and by 2% in other states	−2
Hingson and colleagues (1996)	United States (5 jurisdictions) Varied with each of 5 states examined	Fatal crashes with drivers BAC $\geq$ 0.08 or BAC $\geq$ 0.15	Relative risk comparison	4 of 5 states showed a relative reduction compared with neighboring states that retained 0.10 BAC laws	−16
Hingson and colleagues (2000)	United States (6 jurisdictions) 1988 to 1998	Fatal crashes in FARS	Relative risk comparison	After law implementation, fatal crashes decreased between 4 and 7% within states. Overall, fatal crash rates decreased by 6% compared to neighboring states	−6
Research and Evaluation Associates (REA) (1991)	United States (California 1989 to 1990	Fatal crash rates in FARS	Pre- to postcomparison	The combination of lowering the BAC limit to 0.08 and implementing the ALR law reduced alcohol-related traffic fatalities by 12%	−12
Rogers (1995)	United States (California) 1985 to 1993	Fatal crash rates	Time-series analysis	For fatal crashes, impact of lowering BAC from 0.10 to 0.08 was only detectable after ALR provisions were added	NS
Voas and colleagues (2000)	United States 1982 to 1997	Fatal crash rates in FARS among underage drivers	Weighted least-squares regression models	When examining all drivers, the reduction from BAC 0.10 to 0.08 resulted in a significant reduction in fatal crashes for all drivers. Among underage drivers, however, the reduction of BAC from 0.10 to 0.08, although in the right direction, is not significant. Variable variance among young drivers is likely accounted for by the success of the other MLDA laws	−8
Voas and colleagues (2002)	United States (Illinois) 1989 to 2000	Fatal crash rates in FARS	Time-series analysis (ARIMA)	The proportion of drinking drivers in fatal crashes decreased by 14% in Illinois largely due to the passage of the 0.08 law. Rates in bordering states without the 0.08 law increased by 3%	−14

ARIMA, autoregressive integrated moving average; FARS, fatality analysis reporting system; MLDA, minimum legal drinking age.

Article	Mean	SD	95% CI lower	95% CI upper
Apsler et al., 1999	-0.011	0.036	-0.047	0.025
Asbridge et al., 2015	-0.181	0.063	-0.244	-0.118
Bernat et al., 2004	-0.052	0.027	-0.079	-0.025
Bernhoft & Behrensdorff, 2003	-0.012	0.037	-0.049	0.025
Dee, 2001	-0.067	0.034	-0.101	-0.033
Foss et al., 2001	-0.009	0.021	-0.03	0.012
Gorman et al., 2006	-0.006	0.022	-0.028	0.016
Hingson et al., 1994	-0.024	0.008	-0.032	-0.016
Hingson et al., 1996	-0.161	0.042	-0.203	-0.119
Hingson et al., 2000	-0.06	0.041	-0.101	-0.019
Research and Evaluation Associates, 1991	-0.118	0.037	-0.155	-0.081
Rogers, 1995	-0.01	0.046	-0.056	0.036
Voas et al., 2000	-0.082	0.019	-0.101	-0.063
Voas et al., 2002	-0.146	0.051	-0.197	-0.095

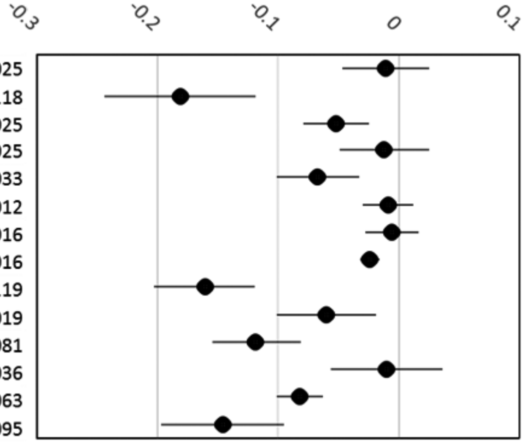

Fig. 4. Mean change in alcohol-related fatal crash rates associated with lowering BAC limit to 0.08.

from 0.08 to 0.05, from 0.08 to 0.03) and a separate analysis conducted for each. Unfortunately, given the relative scarcity of the studies examining the effects of lowering BAC limits on nonfatal alcohol-related traffic crashes, this was not feasible, so 8 of 9 studies (Table 5, Row 2) were combined for a single analysis.

Eight of 9 studies examining the impact on nonfatal alcohol-related crashes demonstrated significant decreases in outcomes. The only study that did not report significant effect sizes (Maisey, 1984) did report decreases in nonfatal alcohol-related crashes, although not of sufficient power to demonstrate significance. When all change values were combined, standardized, and weighted in the meta-analysis, implementation of laws to reduce the illegal BAC limit resulted in a 5.0% decrease in rates of nonfatal alcohol-related crashes.

Reduction in BAC Limit from 0.10 to 0.08 g/dl on Fatal Alcohol-Related Crashes

Our research into the effects of lowering the illegal BAC limit from 0.10 to 0.08 g/dl on fatal alcohol-related crashes yielded 14 suitable studies (Table 5, Row 3). When all change values were combined, standardized, and weighted in the meta-analysis, implementation of laws to reduce the illegal BAC limit from 0.10 to 0.08 g/dl resulted in a 9.2% decrease in the rates of fatal alcohol-related crashes. Of note, though, 12 of these studies were conducted on jurisdictions in the United States, with 1 study examining rates in Canada (Asbridge et al., 2015). Interestingly, the study that found the greatest effect of lowering the BAC limit to 0.08 was the study conducted by Asbridge and colleagues (2015) (−18%) in Canada. This may indicate that the differences in policies and/or cultures between the United States and Canada may have had an additional influence on the effectiveness of the law. As such, we repeated the analysis on the 12 studies conducted in the United States and found a slightly reduced—although still significant—effect on alcohol-related fatal crash rates (−8.4%).

Reduction in BAC Limit to 0.05 g/dl or Lower on Fatal Alcohol-Related Crashes

Finally, we examined studies that examined the impact of lowering illegal BAC limit to 0.05 mg/dl or lower (Table 5, Row 4). Our review found 11 studies that fit our criteria. Four of these studies examined the impact of lowering the illegal BAC limit to 0.05 (Henstridge et al., 1997; Hingson et al., 1998; Homel, 1994; McLean et al., 1995), while the remaining studies examined the effects of lowering the BAC limit to 0.02 or 0.03 (usually from 0.05). Again, an argument can be made that these are 2 fundamentally different types of studies and should thereby be analyzed separately. Unfortunately, given the relative sparsity of research examining the impact of reducing the BAC limit to 0.05 or below, the studies were combined into a single analysis in the current study.

When all change values were combined, standardized, and weighted in the meta-analysis, implementation of laws to reduce the illegal BAC limit to 0.05 or lower resulted in an 11.1% decrease in the rates of fatal alcohol-related crashes. This rate included 1 study by Nagata and colleagues (2008), which as we mentioned briefly above, demonstrated an unusually high effect size. However, even if this study is removed from the analysis, the remaining 10 studies still demonstrate a significant 9.9% reduction in fatal alcohol-related crashes.

Estimated Lives that Would Be Saved with an 11.1% Decrease in the Drinking-Driving Fatal Crash Rate if the United States Adopts a 0.05 g/dl BAC Limit

Following conventions set forth by Fell and colleagues (2016) and given the overall effect sizes of reducing the illegal BAC limit to 0.05 g/dl (11.1%), we estimated how many lives could be saved annually if all 51 jurisdictions in the United States lowered their BAC limit to 0.05. Although rates of fatal alcohol-related crashes have been steadily decreasing since 1983, for estimation purposes we took the average number of fatal alcohol-related crashes over the course of the study. From 1982 to 2014, there was an

Table 4. Mean Change in Fatal Alcohol-Related Crashes Among Studies Evaluating a Reduction of the Illegal BAC Limit to 0.05 g/dl and below

Article	Location/time span	Outcome measure	Analysis used	Results	Change value
Andreuccetti and colleagues (2011)	Brazil 2001 to 2010	Monthly traffic injuries and fatalities	Time-series analysis (ARIMA)	Significant decreases in both traffic injuries and fatalities following law implementation	−2
Assum (2010)	Norway 1995 to 2007	Self-reported drinking and driving, fatal crash rates, and single nighttime vehicle crashes	Chi-square and independent-samples *t*-test	Although drivers reported being less likely to drink before driving after law changes, there were no significant differences in single-vehicle or fatal crashes pre- and post-law implementation	NS
Hingson and colleagues (1998)	United States (Maine) 1982 to 1994	Fatal crashes in FARS for drivers convicted of DWI in prior 3 years	Relative risk comparison	After law implementation, fatal crashes involving drivers with prior DWI declined as a percentage of total crashes while increasing in neighboring states	−13
Homel (1994)	Australia (New South Wales) 1975 to 1986	Fatal crashes for weekend drivers and fatal crashes during the week	Generalized linear modeling	Implementation of the law resulted in a significant decrease in fatal alcohol-related crashes among weekend drivers, but no significant difference was found among weekday drivers	−13
Henstridge and colleagues (1997)	Australia (New South Wales) 1982 to 1992	Number of serious crashes, fatal crashes, and single nighttime vehicle crashes	Time-series analysis (ARIMA)	Reduction of BAC levels to 0.05 resulted in significant decreases in total numbers of all crash types	−11
McLean and colleagues (1995)	Australia 1991 and 1992	BAC levels of fatally injured drivers	None reported	The reduction in permissible BAC laws resulted in a mild and temporary reduction in the BAC levels of fatally injured drivers. No lasting effects noted	NS
Nagata and colleagues (2008)	Japan 1998 to 2004	Traffic fatalities, severe traffic injuries, and all traffic injuries	Segmented regression analysis	All traffic injuries, severe and alcohol-related decreased after law implementation	−38
Nakahara and colleagues (2013)	Japan 1995 to 2006	Monthly police records on fatal road crashes	Jointpoint regression models	Changes detected in trends of alcohol-related crashes had more to do with media events than with changes in BAC legislation	NS
Norström (1997)	Sweden 1987 to 1993	Fatal crashes alone, single-vehicle crashes alone, and all crashes	Time-series analysis (ARIMA)	Significant decreases were found after law implementation in all 3 outcome measures	−10
Smith (1986)	Australia (Tasmania, Western Australia, South Australia) 1980 to 1983	Rates of overall fatal crashes for drivers and motorcyclists	Pre- to postcomparison	In all 3 states, there was a mild but significant impact of BAC reduction and GDL laws on crash rates for both drivers and motorcyclists ranging from 2 to 5%	−18
Živković and colleagues (2013)	Serbia 2006 to 2011	Alcohol use among fatally injured drivers	Independent-samples *t*-test, 1-way ANOVA, and chi-square statistics	No significant effect was found for drivers who were under the influence of alcohol, or levels of alcohol found in their systems. The law appeared to have no notable effect	NS

ARIMA, autoregressive integrated moving average; FARS, fatality analysis reporting system; GDL, graduated driver licensing.

average of 14,339 fatal alcohol-related crashes recorded per year. However, as this number already includes the lives saved by the law, we adjust for the effect of the 0.08 law to obtain an accurate estimate of lives saved by implementing the 0.05 law. Once this is done, we calculated lives saved using the following equation:

$$X = \beta\left(\frac{N}{1-\beta}\right).$$

In this equation, X is the number of lives saved by implementing the 0.08 BAC law, β represents the estimated effect size, and N is the total number of fatal alcohol-related crashes recorded per year. Therefore, a law effect size of 11.1% would result in an estimated 1,790 lives saved annually across the United States. Of note, however, the estimates used in the current endeavor incorporate numerous studies conducted outside of the United States. This necessarily means that international cultural effects and deviations in drinking and/or driving compared to the United States may impact this finding.

DISCUSSION

In our meta-analysis of studies of lowering the BAC limit in general (e.g., from 0.10 to 0.08, from 0.08 to 0.05, or to 0.03), we found no effect on variables related to alcohol use from 5 studies (e.g., reported drinking and driving, attitudes toward drinking and driving, arrests for DWI, positive

Article	Mean	SD	95% CI lower	95% CI upper
Andreuccetti et al., 2011	-0.018	0.007	-0.025	-0.011
Assum, 2010	-0.021	0.026	-0.047	0.005
Hingson et al., 1998	-0.131	0.046	-0.177	-0.085
Homel, 1994	-0.133	0.037	-0.17	-0.096
Henstridge et al., 1997	-0.117	0.042	-0.159	-0.075
McLean et al., 1995	-0.009	0.062	-0.071	0.053
Nagata et al., 2008	-0.384	0.099	-0.483	-0.285
Nakahara et al., 2013	-0.118	0.123	-0.241	0.005
Norström, 1997	-0.1	0.061	-0.161	-0.039
Smith, 1986	-0.181	0.071	-0.252	-0.11
Živković, et al., 2013	-0.019	0.033	-0.052	0.014

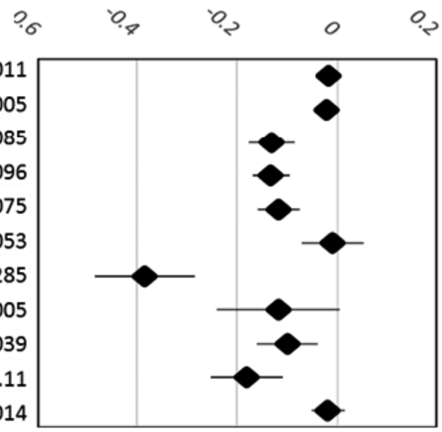

Fig. 5. Mean change in alcohol-related fatal crash rates associated with lowering BAC limit to 0.05.

Table 5. Overall Estimated Mean Impact of Lowering BAC Levels on Alcohol use, Fatal and Nonfatal Alcohol-Related Crashes

Outcome	Number of studies	Estimated impact	Standard deviation
Alcohol consumption-related outcomes (Table 1)	6	−1.4	2.3
Nonfatal alcohol-related crashes (Table 2)	9	−5.0*	2.6
Lowering BAC to 0.08—fatal alcohol-related crashes (Table 3)	14	−9.2*	4.5
Lowering BAC to 0.05 or lower—fatal alcohol-related crashes (Table 4)	11	−11.1*	5.5

*Indicates significance at $p < 0.05$.

breath test results from drivers on the roads). This is important for socioeconomic reasons. Apparently, drivers drank alcohol at the same rate as before the BAC reduction, but somehow avoided driving impaired more often after the BAC change. Possible reasons for this include more use of alternative transportation (e.g., taxis, public transportation, ride-sharing, walking) and drinking beverages with a lower alcohol content. When we consider that 3 other studies did not find meaningful effects, it is not surprising that the overall effect for alcohol use measures is nonsignificant. This result may be due to the nature of the studies used in the analysis. For example, an important factor in reducing rates of alcohol consumption is enhancing public awareness of a law rather than the impact of the law itself (Hingson et al., 2000). As such, it is possible that if the desired effect is to decrease alcohol use and/or increase risk perceptions associated with alcohol, then increasing media exposure to adverse alcohol-related outcomes may prove more beneficial than creating new and/or more stringent legislation.

There was a 5.0% decline in nonfatal alcohol-related crashes (from 8 of 9 studies). While a modest decline, it was significant. There are an estimated 4 million alcohol-related crash injuries annually in the United States (Zaloshnja et al., 2013), so a 5.0% reduction would be substantial. We found a 9.2% decline in fatal alcohol-related crashes from lowering the BAC to 0.08 (from 14 studies), and an 11.1% decline in fatal alcohol-related crashes from lowering the BAC to 0.05 or lower (from 11 studies). These findings are consistent with individual state or multistate studies in the past (Bernat et al., 2004; Dee, 2001; Tippetts et al., 2005; Voas et al., 2000). Based on this potential effectiveness, lowering the BAC limit to 0.05 in the United States should be considered by state and federal safety officials. We estimate that doing so would save 1,790 lives each year if all states adopted a 0.05 BAC limit. Note that lowering the BAC limit to 0.05 did not have a significant effect on reported or measured drinking variables, which should reduce concerns by many opponents in the hospitality industry.

This study provides strong evidence of the relationship between lowering the BAC limit for driving and the general deterrent effect on fatal (and nonfatal) alcohol-related crashes. While there are arguments against lowering the BAC limit to 0.05 g/dl (Fell and Voas, 2014), the life-saving potential seems to be worth any likely negative public or financial effects.

Strengths and Limitations

When conducting a meta-analysis, researchers typically combine studies that are similar in most respects in terms of their outcome variables, settings, and/or populations of interest. In actuality, studies of this kind are rarely very similar and often possess notable differences, which may make comparisons difficult despite efforts to standardize and weight the results. The current analysis is not immune to the differences that exist between studies—primarily in cases where the research is carried out in various countries throughout the world as is the case for much of the 0.05 BAC research presented here. Comparisons of these studies—despite their numerous and noteworthy differences—were deemed as both necessary and prudent.

Further, ideally each of the studies would have been screened for the quality of study conducted—whether comparison groups were used and/or which additional variables were controlled for. This may be particularly relevant as prior research has found that the presence of comparison groups has been shown to reduce the effect size of similar studies examining effects of traffic laws on crash rates (Erke et al., 2009). However, given the complexity of the research question and the relative scarcity of articles, we chose not to further restrict power for the analysis. Future research should consider specific study designs to determine how study quality may impact the relationship between BAC reduction and adverse outcomes.

We also combined studies on lowering the BAC from 0.10 to 0.08 and from 0.08 to 0.03 or 0.02, with the few qualifying studies of lowering the BAC from 0.08 to 0.05. As is the case with any meta-analysis, combining studies with differing, if similar, methodologies and outcomes can artificially inflate or diminish overall effect sizes. Despite this, however, it is common when conducting a meta-analysis to attempt to combine similar studies to improve overall power and thereby reach more meaningful conclusions. Although this is not ideal, it was deemed necessary for the meta-analysis in this study.

This study produced an estimation of the potential effectiveness of lowering the BAC limit for driving from 0.08 to 0.05 based on our analysis of prior research. As in any change in public safety policy, effectiveness will depend on public awareness and attitude toward the change, the enforcement of the law change, and the perception of the risk of arrest or injury by would-be impaired drivers if they exceed the illegal BAC limit.

Finally, although the current study follows methodological considerations appropriate for a meta-analysis, an interesting additional element would have been an examination of the magnitude of predictor effects. That is, it is feasible that studies conducted in the 1980s and 1990s may have had significant methodological differences from those conducted in recent years, which may have impacted the overall meta-effect reported herein. Future research may consider examining this phenomenon in greater detail. Further, future research could metricize BAC to determine exactly how many lives are saved for each 0.01 drop in BAC. Although the scarcity and variability of extant research examining BAC reductions and their effects on fatal crashes prohibit a meaningful examination of this question to date, as studies into this field increases in volume and complexity, this would be an interesting avenue of scientific inquiry.

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