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The relationship between serious injury and blood alcohol concentration (BAC) in fatal motor vehicle accidents: BAC = 0.01% is associated with significantly more dangerous accidents than BAC = 0.00%

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ABSTRACT

Aim To analyze the severity of automotive injuries associated with blood alcohol concentration (BAC) in increments of 0.01%. **Design/setting** Epidemiological study using the Fatality Analysis Reporting System. **Participants** All people in US fatal automotive accidents, 1994–2008 ($n = 1\,495\,667$). **Measurements** The ratio of serious: non-serious injuries for drivers, by BAC. **Findings** Accident severity increases significantly even when the driver is merely 'buzzed', a finding that persists after standardization for various confounding factors. Three mechanisms mediate between buzzed driving and high accident severity: compared to sober drivers, buzzed drivers are significantly more likely to speed, to be improperly seatbelted and to drive the striking vehicle. In addition, there is a strong 'dose–response' relationship for all three factors in relation to accident severity (e.g. the greater the BAC, the greater the average speed of the driver and the greater the severity of the accident). **Conclusions** The severity of life-threatening motor vehicle accidents increases significantly at blood alcohol concentrations (BACs) far lower than the current US limit of 0.08%. Lowering the legal limit could save lives, prevent serious injuries and reduce financial and social costs associated with motor vehicle accidents.

Keywords Accidents, alcohol, automotive accidents, blood alcohol concentration (BAC), buzzed driving, cars, drunk driving, fatalities, injuries, seatbelts, speed, United States.

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INTRODUCTION

A recent laboratory study in this journal found that blood alcohol content (BAC) at levels as low as 0.03% significantly impaired 'cognitive functions which rely on perception and processing of visual information' [1]. This study also found that cognitive impairment was particularly evident for 'more complex and urgent tasks'. Other laboratory studies have similarly found deleterious effects at low BAC [2–7].

While valuable, these laboratory studies suffer two important methodological problems:

1 Laboratory studies cannot examine life-threatening errors, e.g. those resulting in fatal automotive accidents. This limitation exists for both ethical and technical reasons.
2 Laboratory studies are based on small, non-random samples and thus may not hold for large, national populations.

These limitations can be circumvented with an epidemiological examination of fatal automotive accidents.

It is widely acknowledged that a high BAC is the leading risk factor for automotive accidents [8]. However, there is substantial disagreement as to what constitutes a dangerously high BAC, e.g. 0.02% in Sweden, 0.03% in Japan, 0.05% in Germany and 0.08% in the United States [9]. Even within the US, illegal BAC limits have varied from state to state and have changed over the years [10]. This national and international variation suggests that illegal BAC limits are determined not only by rational considerations and by empirical findings, but also by political and cultural factors.

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This paper appears to be the first to use more than a decade of evidence, from all US counties and for all times of day and all days of week, to analyze the relationship between the severity of automotive accidents and individual BAC (in increments of 0.01%) [11–13]. Our findings indicate that accident severity increases significantly even when the driver is merely 'buzzed', i.e. has a BAC much lower than the current US limit of 0.08%. This finding does not appear to be an artifact, and persists after standardization for various confounding factors. We identify three mechanisms mediating between buzzed driving and high accident severity. Our data suggest that it may be appropriate to recalibrate the illegal US BAC limit closer to those used in Sweden and Japan. Lowering this limit could save lives, prevent serious injuries and reduce the financial and social costs of automotive accidents [14–17].

METHODS

We analyzed data from the Fatality Analysis Reporting System (FARS) [18]. At the start of our study, this official US data set was available online from 1994 to 2008 ($n = 1\,495\,667$). We used FARS because it is the only data set we have found which permits analysis of the relationship between BAC and automotive accidents for:

1 all automotive accidents involving at least one fatality;
2 all US counties, all times of day, and all days of the week; and
3 by 0.01% increments in BAC.

Unlike FARS, other major data sets do not provide information on BAC in 0.01% increments. For example, the imputation data set [19] imputes a missing value into one of three broad categories: (i) 0.00%; (ii) 0.01–0.09%; and (iii) 0.10%+. Similarly, other data sets do not provide information on all counties, times of day and days of the week (e.g. the 2007 National Roadside Survey) [20]. As noted, FARS provides complete national information for all times and places. However, it should be emphasized that FARS provides information *only* on accidents with at least one fatality. Thus, our study cannot examine injuries occurring in non-fatal accidents.

Using FARS, we analyzed injury severity, seatbelt use, travel speed, geographic region, each vehicle involved in the accident and the status of each person involved in the accident (e.g. driver, passenger, pedestrian). In addition, we analyzed the driver's BAC (in 0.01% increments) and evidence of drivers' fatigue and inattention. In this data set, inattention refers to talking, eating and cellphone use; these behaviors are not coded individually.

FARS codes injury severity as 'fatal injury', 'incapacitating injury', 'non-incapacitating injury', 'possible injury' and 'no injury'. To examine the risk of serious injury associated with the driver's BAC, we defined the severity ratio:

$$S = \frac{\text{serious injury for a given BAC}}{\text{non-serious injury for a given BAC}} = \frac{\text{incapacitating injury} + \text{fatal injury for a given BAC}}{\text{no injury} + \text{possible injury for a given BAC}}$$

Thus, $S = 5$ indicates an accident involving five times as many serious as non-serious injuries. When calculating S, we excluded the potentially ambiguous category of 'non-incapacitating injury' because it occupied an intermediate position between the serious and non-serious categories. For convenience, we use the term 'dangerous accident' to denote a FARS-reported accident with a large severity ratio (S).

Variants of S [21–23] and case–control designs [11,24,25] have been used to examine this topic, but suffer methodological problems. For example, these studies employ small, geographically and temporally non-representative samples [11,21–25].

Following official recommendations [26] and our previous practice [27–32], we calculated standard errors [33] and significance levels, even though we examined complete counts, not samples. As in previous work [27–32], the study design allows examination of numbers of events, rather than rates.

RESULTS

Figure 1a examines S, the ratio of serious to non-serious injuries for drivers with different BACs (in increments of 0.01%). This examination is limited to people inside the driver's vehicle, and thus excludes pedestrians and other people outside the driver's vehicle.

The figure reveals that S increases significantly even if the driver is merely 'buzzed', i.e. has *any* detectable BAC. Even with a BAC of 0.01%, there are 4.33 (4.05–4.63) serious injuries for every non-serious injury versus 3.17 (3.14–3.19) for sober drivers. The difference between S for these BACs is highly statistically significant ($\chi^2 = 83.11$; 1 d.f.; $P < 0.000001$). For further details on statistical significance, see legend for Fig. 1. Thus, compared to sober drivers, buzzed drivers are associated with significantly more dangerous accidents. Later we assess some mechanisms that could explain this finding.

Table 1 indicates that our principal finding generally holds throughout the US, throughout the study period, and for both single- and multiple-vehicle crashes. For each group, S for buzzed drivers significantly exceeds S for sober drivers. This finding persists even after two potentially confounding variables (inattention and fatigue) are excluded from the analyses [$S = 3.04$ (3.01–3.06) for BAC = 0.00%; $S = 4.21$ (3.92–4.51) for BAC = 0.01%; $\chi^2 = 80.48$; 1 d.f.; $P < 0.000001$].

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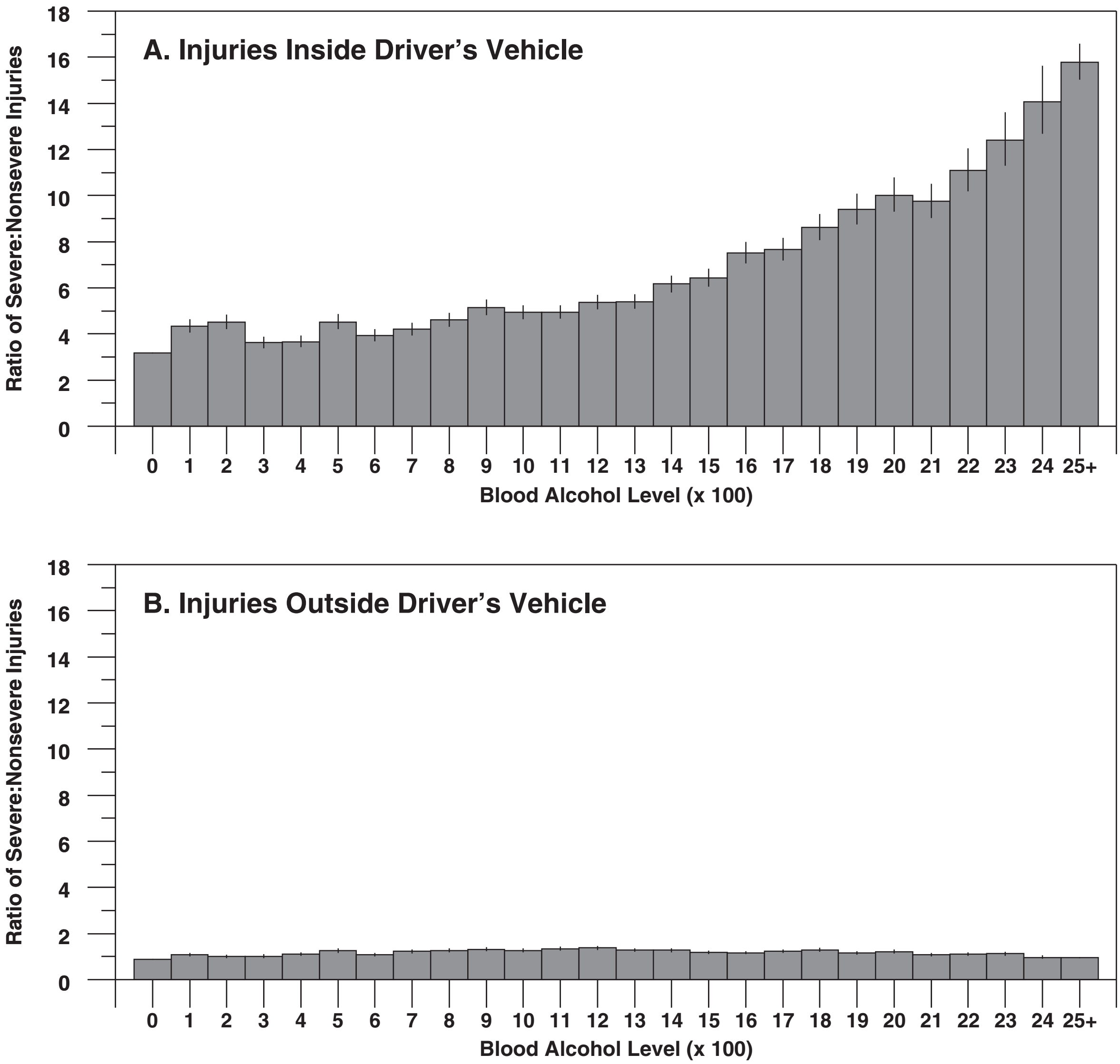

Figure 1 Injury severity ratio by driver's blood alcohol concentration (BAC) for injuries inside versus injuries outside the driver's vehicle, United States, 1994–2008. (a) $\chi^2 = 83.11$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 248 483, non-severe injuries = 78 460; for BAC = 0.01%: severe injuries = 4548, non-severe injuries = 1050). (b) $\chi^2 = 38.07$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 74 196, non-severe injuries = 84 082; for BAC = 0.01%: severe injuries = 1867, non-severe injuries = 1718). Data provided by Fatality Analysis Reporting System [18]. Error bars were calculated using formulas provided by Gardner & Altman [33]

Table 1 Injury severity ratio by driver's blood alcohol concentration (BAC) for injuries inside the driver's vehicle by time-period, by region and for single- and multiple-vehicle crashes, United States, 1994–2008.

	BAC = 0.00%	*BAC = 0.01%*	χ^2	*P*
1994–98	3.27 (3.22–3.32)	4.11 (3.67–4.61)	15.41	<0.0001
1999–2003	3.09 (3.05–3.13)	4.76 (4.22–5.36)	50.82	<0.0001
2004–08	3.15 (3.11–3.19)	4.16 (3.70–4.66)	21.85	<0.0001
Midwest	2.80 (2.75–2.84)	5.18 (4.53–5.91)	84.58	<0.0001
Northeast	4.23 (4.12–4.35)	5.54 (4.56–6.71)	7.5	0.0062
South	3.01 (2.97–3.05)	4.34 (3.87–4.86)	40.36	<0.0001
West	3.56 (3.50–3.63)	3.06 (2.68–3.49)	5.02	0.0250
Single-vehicle	3.08 (3.04–3.11)	3.97 (3.65–4.31)	35.34	<0.0001
Multiple-vehicle	3.11 (3.08–3.15)	4.89 (4.44–5.37)	87.86	<0.0001

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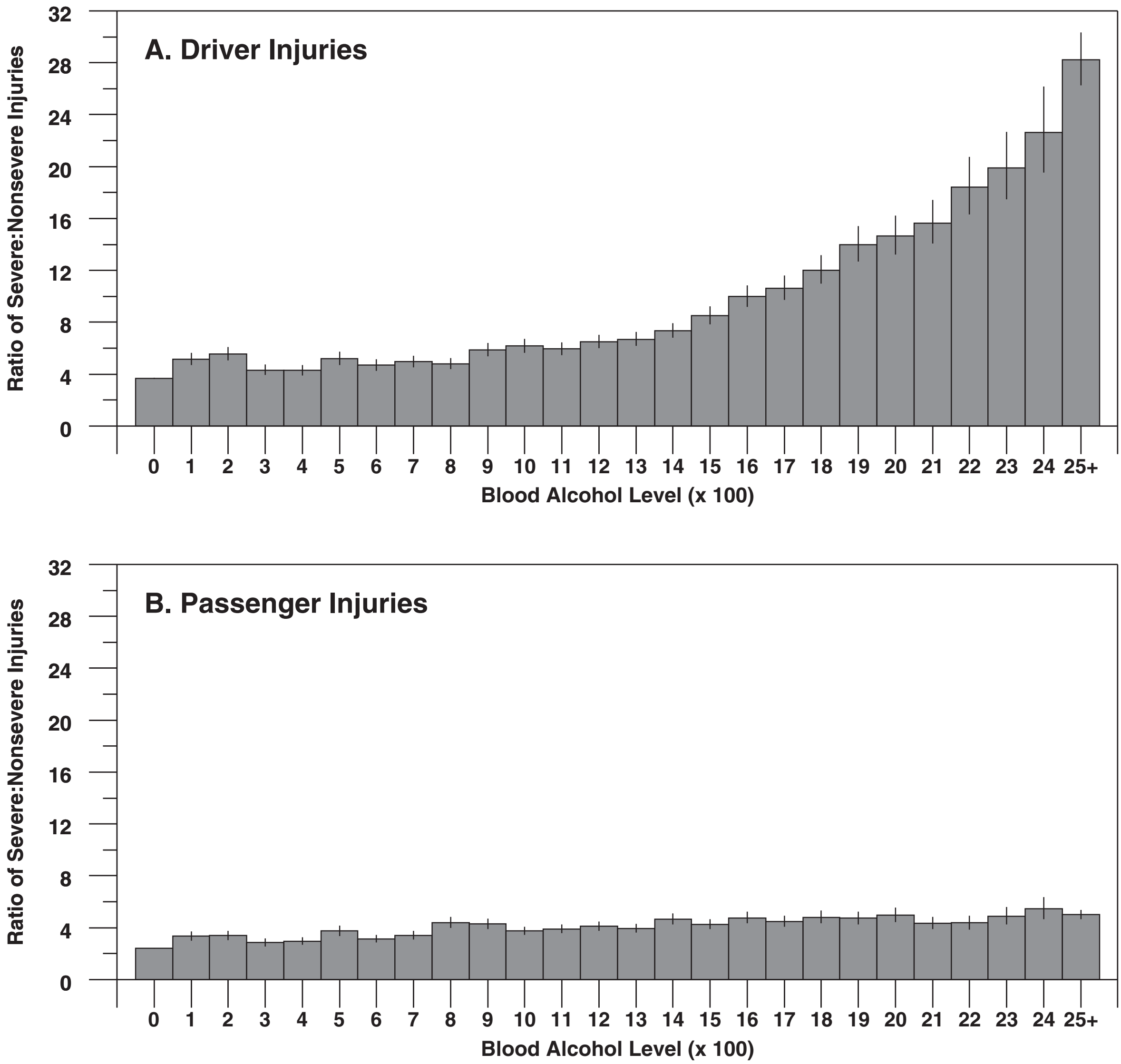

Figure 2 Injury severity ratio by driver's blood alcohol concentration (BAC) for driver injuries versus passenger injuries inside the driver's vehicle, United States, 1994–2008. (a) $\chi^2 = 55.00$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 173 668, non-severe injuries = 47 293; for BAC = 0.01%: severe injuries = 2945, non-severe injuries = 571). (b) $\chi^2 = 39.72$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 74 798, non-severe injuries = 31 074; for BAC = 0.01%: severe injuries = 1603, non-severe injuries = 479). Data provided by Fatality Analysis Reporting System [18]. Error bars were calculated using formulas provided by Gardner & Altman [33]

Unlike Fig. 1a, Fig. 1b is limited to people *outside* the driver's vehicle (pedestrians or occupants of another vehicle). To facilitate comparison, panels (a) and (b) are plotted to the same scale. Figure 1b is similar to Fig. 1a in one important respect: for people outside the driver's vehicle, S increases significantly even if the driver is merely buzzed [$S = 0.88$ (0.87–0.89) for BAC = 0.00%; $S = 1.09$ (1.02–1.16) for BAC = 0.01%; $\chi^2 = 38.07$; 1 d.f.; $P < 0.000001$]. However, unlike Fig. 1a, Fig. 1b reveals a low severity ratio, barely changing by BAC. Thus, Fig. 1 reveals that variation in injury severity by BAC is most striking for people *inside* the driver's vehicle. Henceforth, we focus on this group.

Figure 2a is limited to *driver* injuries. As in Fig. 1a, S increases significantly even if the driver is merely buzzed [$S = 3.67$ (3.63–3.71) for BAC = 0.00%; $S = 5.16$ (4.71–5.64) for BAC = 0.01%; $\chi^2 = 55.00$; 1 d.f.; $P < 0.000001$].

Figure 2b is limited to *passenger* injuries. To facilitate comparison, panels (a) and (b) are plotted to the same scale. For people outside the driver's vehicle, S increases significantly even if the driver is merely buzzed [$S = 2.41$ (2.38–2.44) for BAC = 0.00%; $S = 3.35$ (3.02–3.70) for BAC = 0.01%; $\chi^2 = 39.72$; 1 d.f.; $P < 0.000001$]. However, unlike Fig. 2a, Fig. 2b reveals a low severity ratio, barely changing by BAC.

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Table 2 Injury severity ratio by driver's blood alcohol concentration (BAC) for driver injuries by time-period, by region and for single- and multiple-vehicle crashes, United States, 1994–2008.

	BAC = 0.00%	*BAC = 0.01%*	χ^2	*P*
1994–98	3.67 (3.61–3.74)	4.78 (4.08–5.57)	10.89	0.0010
1999–2003	3.56 (3.50–3.62)	5.46 (4.66–6.38)	28.76	<0.0001
2004–08	3.79 (3.72–3.85)	5.24 (4.49–6.11)	17.1	<0.0001
Midwest	3.04 (2.98–3.10)	6.05 (5.06–7.20)	60.38	<0.0001
Northeast	5.24 (5.06–5.41)	6.67 (5.22–8.47)	3.81	0.0508
South	3.47 (3.42–3.53)	5.44 (4.65–6.35)	32.43	<0.0001
West	4.40 (4.30–4.50)	3.30 (2.76–3.93)	9.99	0.0016
Single-vehicle	3.56 (3.50–3.61)	4.59 (4.09–5.15)	18.88	<0.0001
Multiple-vehicle	3.53 (3.49–3.58)	5.86 (5.16–6.63)	63.35	<0.0001

Table 2 focuses on *driver* injuries and indicates, once again, that our principal finding generally holds throughout the US, throughout the study period, and for single- and multiple-vehicle crashes. For each group, *S* for buzzed drivers significantly exceeds *S* for sober drivers. This finding persists even after two potentially confounding variables (inattention and fatigue) are excluded from analyses [$S = 3.52$ (3.48–3.56) for BAC = 0.00%; $S = 4.98$ (4.53–5.47) for BAC = 0.01%; $\chi^2 = 52.23$; 1 d.f.; $P < 0.000001$].

Figure 3 indicates that the high *S* for buzzed drivers persists for key subgroups. The first set of bars in Fig. 3 displays *S* for the most general category, group 1: all people inside the driver's vehicle. The second set of bars selects within group 1: only drivers. The third set of bars selects within group 2: only drivers showing no evidence of fatigue or inattention. The fourth set of bars selects within group 3: only drivers who show no evidence of fatigue or inattention *and* are involved in single-vehicle crashes. For all these groups and subgroups, buzzed drivers are associated consistently with significantly more dangerous accidents than are sober drivers.

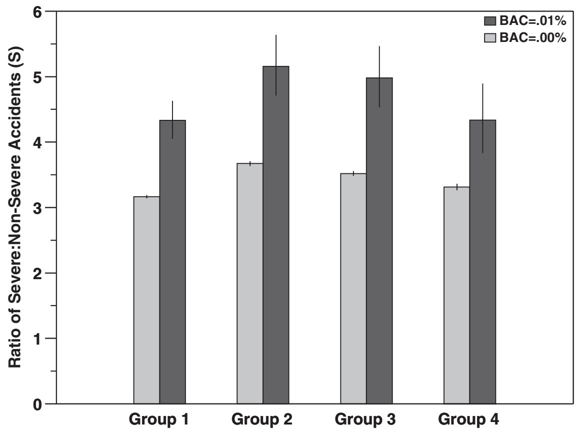

Figure 3 Injury severity ratio for driver's blood alcohol concentration (BAC) = 0.00% versus driver's BAC = 0.01%, for various groups, United States, 1994–2008. Group 1 (all persons inside the driver's vehicle): $\chi^2 = 83.11$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 248 483, non-severe injuries = 78 460; for BAC = 0.01%: severe injuries = 4548, non-severe injuries = 1050). Group 2 (only drivers): $\chi^2 = 38.07$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 173 668, non-severe injuries = 47 293; for BAC = 0.01%: severe injuries = 2945, non-severe injuries = 571). Group 3 (only drivers with no evidence of fatigue or inattention): $\chi^2 = 52.24$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 153 604, non-severe injuries = 43 637; for BAC = 0.01%: severe injuries = 2600, non-severe injuries = 522). Group 4 (only drivers with no evidence of fatigue or inattention *and* are involved in single vehicle crashes): $\chi^2 = 18.57$; 1 d.f.; $P < 0.00001$ (for BAC = 0.00%: severe injuries = 70 816, non-severe injuries = 21 379; for BAC = 0.01%: severe injuries = 1379, non-severe injuries = 318). Data provided by Fatality Analysis Reporting System [18]. Error bars were calculated using formulas provided by Gardner & Altman [33]

DISCUSSION

This paper appears to be the first to use more than a decade of evidence, from all US counties and for all times of day and all days of the week, to analyze the relationship between accident severity and BAC (in increments of 0.01%). Most notably, this paper appears to be the first to indicate that buzzed drivers are associated with significantly more dangerous accidents than are sober drivers.

We now consider whether these findings result from artifact or from confounding variables. We then assess three mechanisms that appear to mediate between buzzed driving and accident severity.

Are our findings an artifact of missing BAC measurements?

In our data set [18], 66% of all driver BACs were unreported. The majority of these unreported levels (86.4%) are cases where BAC was not measured. The remaining unreported BAC cases are distributed as follows: 'unknown if tested/not reported' (8.3%); 'alcohol test performed, results unknown' (5.2%); 'test refused' (0.1%); and 'positive reading with no actual value' (0.0%).

Perhaps unreported BAC in some (presently unknown) fashion explains our principal finding that S for buzzed drivers significantly exceeds S for sober drivers. The following analysis undermines this 'artifact hypothesis'.

In the 15 years under study, there has been a significant downward trend in the percentage of cases with unreported BAC (slope = –0.22; correlation = –0.75; $n = 15$; $t = -4.10$; $P = 0.00062$). Therefore, given the artifact hypothesis, there should be a corresponding downward trend in the degree to which S for buzzed drivers exceeds S for sober drivers (measured by the ratio $R = S[\text{BAC} = 0.01\%]/S[\text{BAC} = 0.00\%]$). However, contrary to this expectation, there is no correlation between the yearly value of R and the yearly value of the percentage of cases with unreported BAC (correlation = 0.19; $n = 15$; $t = 0.68$; P = not significant). In sum, the degree to which BAC is unreported is *not* associated with the disparity between S for buzzed drivers and S for sober drivers; this undermines the artifact hypothesis.

FARS generates two data sets: the first [18], which we used, relies only on actual data and thus includes some unreported BAC. The second [19] (known as the imputation file) relies on a mix of actual and imputed data. In this imputed data set, FARS 'employs a statistical model to estimate the likelihood that a fatal crash-involved driver or nonoccupant was sober (BAC of zero), had some alcohol (BAC of 0.01–0.09), or was intoxicated (BAC of 0.10 or greater) at the time of the crash' [18].

One might suppose that this imputed data set could be used to circumvent possible problems associated with unreported BAC. However, our analysis requires S for BAC in increments of 0.01%, and these individual values are not provided by the imputation data set. Instead, this data set imputes a missing value into one of three broad categories: (i) 0.00%; (ii) 0.01–0.09%; and (iii) 0.10%+. Thus, although the imputation data set may be valuable for other purposes [11], it cannot be used in our analysis.

Do our findings result from confounding variables?

Above, we showed that our principal finding persists after correction for some potentially confounding variables. Here, we examine additional confounding variables. In these and subsequent analyses, we restrict attention to driver injuries.

Hour of day

S is unusually high from 8 p.m.–4 a.m. [$S = 2.13$ (2.11–2.15) versus S for 4 a.m.–7 p.m. = 1.72 (1.71–1.73); $P < 0.000001$]. If hour of day accounts for the BAC–S relationship, then this relationship should disappear once we standardize on hour of day: for each hour individually, we compared S for buzzed versus sober drivers. For 23/24 hours, S for BAC = 0.01% exceeds S for BAC = 0.00% ($n = 24$; $x \geq 23$; $P < 0.000001$; binomial test). Thus, our findings persist after standardizing on hour of day.

Day of week

S is significantly higher during weekends [$S = 2.16$ (2.14–2.18) versus S for weekdays = 1.70 (1.70–1.71); $P < 0.000001$]. If day of the week accounts for the BAC–S relationship, then this relationship should disappear once we standardize on day of the week: for each day individually, we compared S for buzzed versus sober drivers. For all 7 days, S for BAC = 0.01% exceeds S for BAC = 0.00% ($n = 7$; $x \geq 7$; $P = 0.008$; binomial test). Thus, our findings persist after standardizing on day of the week.

Month of year

S is significantly higher during June–August [$S = 1.94$ (1.93–1.96) versus S for the remaining months = 1.80 (1.79–1.81); $P < 0.000001$]. If month accounts for the BAC–S relationship, then this relationship should disappear once we standardize on month: for each month individually, we compared S for buzzed versus sober drivers. For all 12 months, S for BAC = 0.01% exceeds S for BAC = 0.00% ($n = 12$; $x \geq 12$; $P < 0.000001$; binomial test). Thus, our findings persist after standardizing on month.

Age of vehicle

On average, buzzed drivers operate vehicles that are slightly older (by 0.65 years) than are vehicles operated by sober drivers. Accident severity increases by vehicle age (i.e. model year) because older vehicles are less safe. For model years 1965–2008, S is correlated strongly with model year ($r = -0.84$; $t = -10.14$; $n = 44$; $P < 0.000001$). If model year accounts for the BAC–S relationship, then this relationship should disappear once we standardize on model year.

We used two techniques to standardize on model year, as follows.

1. The first technique mirrors those used above, except that it omits rare model years where the number of cases is insufficient to calculate a meaningful S: We examined only model years where the number of cases exceeded 100. Seventeen model years met this criterion. For each of these model years individually, we compared S for buzzed versus sober drivers. For 16 of 17 model years, S for BAC = 0.01% exceeds S for BAC = 0.00% ($n = 17$; $x \geq 16$; $P < 0.000001$; binomial test).

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2 The first technique is meaningful, but omits rare model years. The second technique does not. We identified the model year for each buzzed driver. Then, from sober drivers, we randomly selected 28 cases with the same model year. This technique standardizes on model year by ensuring that the distribution of model years is the same for sober as for buzzed drivers. *S* for buzzed drivers [5.15 (4.71–5.63)] significantly exceeds *S* for the standardized sober drivers [3.63 (3.57–3.69); $P < 0.000001$]. Thus, both standardization techniques indicate that model year cannot account for our findings.

In sum, our principal finding persists after correction for various confounding variables.

Possible mechanisms mediating between BAC and *S*

Several factors help to explain why accident severity is elevated even for drivers with a BAC as low as 0.01%.

Speed

After aggregating speed into 10 groups [0–9 miles per hour (mph), 10–19 mph, . . . , 90 + mph], we found a strong correlation between travel speed and *S* ($r = 0.83$; $t = 4.15$; $n = 10$; $P = 0.002$). Similarly, there is a strong correlation between BAC and *S* (for Fig. 1a, $r = 0.89$; $t = 9.42$; $n = 26$; $P < 0.000001$). Perhaps the BAC–*S* correlation occurs partly because BAC correlates with speeding. The data support this supposition: driver's BAC correlates strongly with travel speed ($r = 0.88$; $t = 9.04$; $n = 26$; $P < 0.000001$). Notably, the average speed even for buzzed drivers [51.39 (50.30–52.48)] significantly exceeds the average speed for sober drivers [48.49 (48.35–48.63); $Z = 5.18$; Z-test for differences between averages; $P < 0.000001$]. Thus, the tendency for buzzed drivers to speed helps to explain why buzzed drivers are associated with severe accidents.

Seatbelts

Improperly restrained drivers have an unusually high *S* [8.43 (8.32–8.53) versus 1.03 (1.02–1.04) for properly restrained drivers; $P < 0.000001$]. Perhaps the BAC–*S* correlation occurs partly because BAC correlates with improper restraint. The data support this supposition: the greater the driver's BAC, the more likely she/he is to be improperly restrained ($r = 0.96$; $t = 17.79$; $n = 26$; $P < 0.000001$). Even for buzzed drivers, the ratio of unrestrained : restrained drivers (1.00 = 1761/1764) significantly exceeds this ratio for sober drivers [0.63 = 86 049/136 141; $\chi^2 = 184.10$, 1 d.f.; $P < 0.000001$]. Thus, the tendency for buzzed drivers to be improperly restrained helps to explain why buzzed drivers are associated with severe accidents.

Striking versus struck vehicle

S for the striking vehicle significantly exceeds *S* for the struck vehicle [1.91 (1.90–1.92) versus 1.33 (1.31–1.34); $P < 0.000001$]. Perhaps the BAC–*S* correlation occurs partly because drinking drivers are unusually likely to operate the striking vehicle. The data support this supposition: the greater the driver's BAC, the more likely she/he is to be operating the striking vehicle ($r = 0.90$; $t = 10.18$; $n = 26$; $P < 0.000001$). Even for buzzed drivers, the ratio of striking : struck vehicles (3.35 = 2654/793) significantly exceeds this ratio for sober drivers [2.54 = 156 178/61 460; $\chi^2 = 45.95$, 1 d.f.; $P < 0.000001$].

In sum, compared to sober drivers, buzzed drivers are significantly more likely to speed, to be improperly restrained and to drive the striking vehicle. Each of these conditions is associated with unusually severe accidents. In addition, there is a strong 'dose–response' relationship between all these factors: e.g. the greater the BAC, the greater the average speed of the driver and the greater the severity of the accident. Taken together, these findings strongly suggest at least three mechanisms which help to explain why even very low BAC is linked to high accident severity. Two of these mechanisms involve driving skill: speed and operating the striking vehicle. One mechanism is unrelated (or indirectly related) to driving skill: use of seatbelts.

Advantages and limitations of our study design

Our study design has several advantages, which allowed us to:

1 analyze BAC in individual increments of 0.01%;
2 analyze life-threatening injuries;
3 use an official, exhaustive, nation-wide, 15-year data set;
4 examine all counties, all times of day and all days of the week; and
5 examine an important and frequently overlooked variable: accident severity (*S*)

However, our study design is limited in one important way: our measure, *S*, examines only one aspect of crashes: the severity of an accident once it has occurred. It would also have been desirable to evaluate an additional measure, *S′*. This measure examines the risk of an accident occurring:

$$S' = \frac{\text{number of serious injuries for a given BAC}}{\text{number of person-miles traveled for a given BAC}}$$

Unfortunately, the information needed for *S′* is not known for the entire US, but only for small, geographically non-representative samples [8]. This limitation holds for any study seeking to examine accident risk, classified by detailed BAC, for the entire US.

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Research and policy implications

1 Our study appears to be the first to find that accident severity increases significantly even if the driver is merely buzzed. Heretofore, laboratory studies of alcohol have found psychomotor effects at BAC as low as 0.02% [2–7]. However, our non-laboratory findings suggest that researchers should seek harmful effects of alcohol at an even lower BAC.

2 It might be surprising that the skills of a buzzed driver could be sufficiently degraded to increase the severity of an accident. Our evidence sheds some light on this question: for example, we found that buzzed drivers drive significantly faster than sober drivers and are significantly less likely to wear seatbelts. We found that both these factors are associated with high accident severity. Future research should seek to determine additional mechanisms by which a low BAC degrades driving safety. It might be convenient to divide these mechanisms into those related to driving skill (e.g. speed and aggression) and those unrelated (or indirectly related) to driving skill (e.g. failure to use seatbelts and increased fragility associated with positive BACs).

3 Our study uses a measure often overlooked in earlier research: the ratio of serious to non-serious injuries. This 'injury severity ratio' could be used to supplement traditional approaches, [11,21–25], e.g. in 'culpability studies' [25,34].

4 Our study appears to be the first to use BAC in increments of 0.01% to provide nation-wide, detailed, evidence-based grounds for recalibrating legal BAC limits. This evidence enables future researchers and legislators to refine the meaning of terms such as 'buzzed', 'impaired' and 'intoxicated'.

CONCLUSION

Automotive accidents are an important national problem. In the last year of our study period, there were 50 430 vehicles and 84 026 people involved in fatal automotive accidents; of these, there were 37 261 deaths and 10 048 incapacitating injuries [18]. A high BAC is widely acknowledged to be the leading risk factor for these accidents [8]. Consequently, many industrialized nations have set illegal BAC limits, ranging from 0.02% for Sweden and 0.03% for Japan to 0.08% for the US [9].

Our findings are consistent with but extend earlier laboratory studies [2–7]: accident severity increases significantly at BAC levels far lower than the current US limit of 0.08%. We found three mechanisms that help to explain this finding; additional mechanisms may be discovered in future research. Whatever the mechanisms involved, our evidence suggests that it may be appropriate to recalibrate the US BAC limit closer to the lower limits used in Sweden and Japan. Our data suggest that lowering the US limit could save lives, prevent serious injuries and reduce the substantial financial and social costs associated with automotive accidents [14–17].

Declarations of interest

David P. Phillips and Kimberly M. Brewer have no conflicts of interest to disclose. Research was funded by the Marian E. Smith Foundation. No member of the Marian E. Smith Foundation participated in the production of this study.

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