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STATISTICAL RELATIONSHIP BETWEEN PRESUMPTIVE BLOOD ALCOHOL CONCENTRATION LIMITS OF ILLEGALITY AND MEASURED BAC'S OF DRUNK DRIVERS*

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Apprehended drunk driving offenders frequently submit to chemical tests for determining the amount of alcohol in their blood. The measurement, called the blood alcohol concentration (BAC), is expressed in terms of weight of alcohol per unit volume of blood (milligrams per 100 milliliter). For convenience here the popular expression "0.XX%" will be used.

Many states have created a statutory presumptive BAC limit of illegality for persons driving motor vehicles. Offenders whose measured BAC exceeds (or equals in some cases) the presumptive limit are presumed to be guilty of the charged drunk driving offense. Two presumptive limit standards prevail among the states: 0.10% and 0.15%. Hereafter states having a 0.10% presumptive limit will be referred to as "0.10%" states and states having a 0.15% presumptive limit will be referred to as "0.15%" states.

This paper reports the results of an empirical investigation of several questions, including the following: In the populations of persons apprehended on drunk driving charges and tested for BAC, is the proportion having BAC test results less than 0.14% a greater part of the tested population in 10% states than in 15% states? Analyses of data from 39 states (twenty-one 15% states and eighteen 10% states) answer the question affirmatively with high statistical probability that the null hypothesis (that is, that no difference exists) has not been erroneously rejected by chance.

Although these data and analyses do not support a firm conclusion that a 0.10% presumptive limit causes a greater proportion of "less-drunk" drivers (below 0.14% BAC) to be arrested than does a 0.15% presumptive limit, they do show that a lower presumptive limit is associated with that result in the data studied here. If one were to show that all other causative factors were equal in the two sample spaces (for example, that the distributions of BAC's in the populations of drivers were the same and that law enforcement practices were otherwise the same), then the inference of causative relationship would be strong. Common sense and experience suggest, however, that all other things are not equal in the various populations represented. Moreover, the data themselves show variability in other respects. Nevertheless, the stated association has been shown to exist in these data, providing at least one piece of circumstantial evidence in support of an assertion that lowering the presumptive limit from 0.15% to 0.10% will increase the proportion of less-drunk drivers (that is, those with BAC's less than 0.14%) arrested in the total population of arrestees. If this were to be true, it would seem to follow that more drunk drivers would be arrested (assuming nothing arbitrarily limits the number to be arrested) in a 15% state if the presumptive limit were lowered to 0.10%.

BACKGROUND

Popular belief has it that one means of reducing serious highway crashes is to arrest a greater number of people for driving while intoxicated. Originally, it was thought that rigorous enforcement per se would deter drinkers from driving while

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drunk. Now, in light of better understanding of the alcoholic component of drunken driving and, especially of the U.S. Department of Transportation's countermeasures efforts, it is thought that arrests can lead to treatment and, hence, to less drunk driving and fewer crashes. A second important factor has been recognized as a key in attaining that goal. It is not just the grossly intoxicated driver that is a highway menace. Research data suggest that the risk to crash of an "average" driver multiplies many times when by imbibing intoxicants he has raised his blood alcohol concentration (BAC) to 0.10% or less. Despite that the legal presumptive limit of intoxication remains at 0.15% in 21 states and at 0.10% in 24 others. Only Utah has a lower limit (0.08%), and 4 states have no presumptive limit at the moment. Moreover, research data show also that very few people arrested on drunk driving charges yield BAC test results of less than 0.15%.

This can be viewed as a grave oversight. Probably more people drive with BAC's between 0.05% and 0.10% than with BAC's of greater than 0.10%. Furthermore, drivers that wind up grossly intoxicated necessarily pass through less intoxicated stages. Yet, fewer members of the moderately intoxicated group are arrested, despite the facts that they are at higher risk than when sober; many may suffer from alcoholism in some degree, and of those some will become grossly intoxicated by continuing to drink.

Several proposals have been made for arresting "less-drunk" drinking drivers. Popular among them is to lower the presumptive limit, thereby making it easier to obtain convictions and judicial control over them. It can be argued on at least two grounds, however, that this is a pointless step. In the first place less-drunk drivers frequently do not lay down the trail of classical drunk driving clues that enforcement officers tune in to. In the second place, once stopped by an officer, a less-drunk driver has greater likelihood of avoiding a drunk driving arrest by marshalling his faculties and presenting rationale demeanor and argument. Hence, it can be argued that lowering presumptive limits would not be productive in producing more arrests.

Nevertheless, under pressure from the Department of Transportation a trend toward the 0.10% limit has developed. The basis for it is logic and opinion rather than scientific proof. This situation may be improved, however. Because two presumptive limit standards are prevalent among the states, it is possible to augment present arguments with empirical studies. That was the purpose of the investigation reported here.

Data Sources

Collecting reliable BAC data is not done without difficulty. Many police jurisdictions do not retain adequate records, and no state known to the writer assimilates all data from the state in one location. Accordingly, a goal of one data source from each state was set. Because it was believed that city police officers are exposed to a wider spectrum of circumstances than are officers from either state police or sheriff departments, city police authorities were chosen as the appropriate data sources. Accordingly, one city was chosen as the representative data source for each state.

In making selections, cities in the 100,000 to 200,000 population size were aimed for with the intention both of avoiding special data handling difficulties that might occur in larger cities and of obtaining samples of sufficient size to be statistically reliable. Obtaining all the drunk driver BAC data generated in each city during the year 1969 was the survey goal. Several mailings were required before the final sample (which does not include a representative city from 11 of the 50 states) was obtained. In some states several cities were written before suitable data were received in reply and in a few cases no data were ever obtained. Some cities did not reply; some had no data; some had no chemical test program in 1969; and some provided data that were defective. The final test sample was sizeable, however, containing 15,524 BAC data points, made up of 8,322 from 15% states and 7,202 from 10% states. Participating jurisdictions are listed in appendix A.

Detailed instructions were submitted with each request for data. The addressees were asked to record the BAC result of every tested drunk driving offender in two decimal place increments beginning at 0.00% (zero alcohol content) and going up through the highest test score attained. (The highest recorded in these data was 0.57%). In cases where tests were officially recorded in digits of three decimal places, the instructions called for always rounding down to the next lower two-decimal place digit. In addition to stating the data conservatively low, that procedure makes possible a statement that a given proportion of test results is below some designated figure. (For example, that the proportion of offenders having BAC's below 0.14% is statistically significantly different in two distributions.)

Addressees were also asked to state the number of persons that refused to submit to a chemical test and the number that was not tested for some other reason (for example, not asked to submit, machine broken, operator off duty, etc.). The reported data show that about three persons are tested for each person not tested. In the survey jurisdictions 5,178 non-tested persons were reported, broken down into 4,457 refusals and 729 not tested for other reasons. A substantially higher proportion was tested in 15% states (3.4 to 1) than in 10% states (2.7 to 1).

DATA

The BAC data and some statistics are displayed in Table 1. Brief comment will be made about the information contained in each of the numbered sections.

Section one contains the basic BAC frequency distributions for four sample populations:

Total sample: lumped data from all 10% and 15% states
15% states: lumped data from all 15% states
10% states: lumped data from all 10% states
Utah: data from Utah, the only 0.08% state

Although the data were collected in 0.01% increments, they are presented in groupings covering 0.05% increments for convenience.

Section two records the percentage the number of counts in each grouping category is of the total population. Note the similarity of the 10% states to the 15% states in the middle groupings and the dissimilarity in the groupings in each tail of the distributions.

Section three records cumulative percentages beginning at the lowest BAC test grouping and proceeding through the highest. Note that the cumulative percentage of tests up through the 0.10%–0.14% grouping is substantially greater in the 10% states than in 15% states.

Section four through six present four basic statistics for each distribution: mean, standard deviation of the counts, median, and mode. Note that all these quantities are lower in 10% states than in 15% states.

Sections seven through nine present data and statistics describing the number of persons that were not tested in the various jurisdictions. The sum of the people apprehended and tested and those apprehended and not tested should be the total number of people apprehended. Several factors could explain the absence of a test in any given case. One is that the person exercised his option not to comply. In implied consent states the refusing person in most cases would automatically suffer a license suspension for a prescribed period of time as consequence of his refusal. That option, however, could be more palatable than a drunk driving conviction which could be made highly probable by a BAC test above the presumptive limit. Therefore, it can be argued that the lower the presumptive limit the greater the incentive not to submit to a test. Comparing data from 10% states to those of 15% states, one sees that the proportion of refusals is greater in 10% states.

Sections ten and eleven contain population data and statistics. The data, obtained from 1970 census tracts, suggest that more BAC tests are given per capita in 10% states than in 15% states.

HYPOTHESES AND RESULTS OF STATISTICAL TESTS

The general question under examination is whether less-drunk drivers (BAC less than 0.14%) are more likely to be arrested in 10% states than in 15% states. If so, it can be argued that lowering the presumptive limit in 15% states will result in more less-drunk drivers being brought within the scope of judicial control. Although it is not necessary here to argue whether that is a desirable goal, some people believe it is, as earlier remarks indicate.

Data obtained from eighteen 10% states lumped into one population of apprehended and tested drunk driving offenders (n = 7202) and data from twenty-one 15% states were lumped into another (n = 8322). The following hypotheses concerning these two sampled populations were tested probabilistically:[1]

> *One:* In the two populations the proportion of persons having BAC's less than 0.14% is no different in states having a 0.10% presumptive limit than in states having a 0.15% presumptive limit.

On the basis of data gathered in this study and the statistical analysis employed, hypothesis one was rejected at the 99.9% probability level. This means that the chance of erroneously rejecting the null hypothesis, if it were true, is 1 in 1000 or less. The data show a greater proportion of cases falling

[1] A description of the statistical testing scheme and statistics are to be found in Appendix B.

Table 1

BAC DISTRIBUTIONS AND STATISTICS

BAC Category	Total Sample (n = 15524)	0.15% States (n = 8322)	0.10% States (n = 7202)	0.08% Utah (n = 320)
1. (FREQUENCIES)				
01–04	217	105	112	20
05–09	551	230	321	38
10–14	1987	851	1136	75
15–19	4576	2399	2177	76
20–24	4650	2592	2058	68
25–29	2546	1511	1035	31
30–34	801	522	279	8
35–39	165	96	69	3
40–44	23	13	10	1
45–49	6	3	3	0
50–57	2	0	2	0
2. (PERCENTAGES)				
01–04	1.40%	1.26%	1.56%	6.25%
05–09	3.55	2.76	4.46	11.87
10–14	12.80	10.23	15.77	23.44
15–19	29.48	28.83	30.23	23.75
20–24	29.95	31.15	25.58	21.25
25–29	16.40	18.16	14.37	9.69
30–34	5.16	6.27	3.87	2.50
35–39	1.06	1.15	0.96	0.94
40–44	0.15	0.16	0.14	0.31
45–49	0.04	0.04	0.04	0.00
50–57	0.01	0.00	0.03	0.00
3. (CUM. PERCENT.)				
01–04	1.40%	1.26%	1.56%	6.25%
05–09	4.95	4.02	6.02	18.12
10–14	17.75	14.25	21.79	41.56
15–19	47.23	43.08	52.02	65.31
20–24	77.18	74.23	80.60	86.56
25–29	93.58	92.39	95.97	96.25
30–34	98.74	98.66	98.84	98.75
35–39	99.80	99.81	99.80	99.69
40–44	99.95	99.97	99.94	100.00
45–49	99.99	100.01	99.98	100.00
50–57	100.00	100.01	100.01	100.00
4. MEAN BAC (S.D.)	0.199 (±.063)	0.205 (±.063)	0.192 (±.063)	0.163 (±.076)
5. MEDIAN BAC	0.20	0.20	0.19	0.17
6. MODE BAC	0.20	0.20	0.19	0.18
7. # TESTS REFUSED	4457	2105	2352	15
8. # TESTS NOT GIVEN	729	439	290	3
9. # TESTED ÷ NOT TESTED	3.0	3.3	2.7	17.8
10. ESTIMATED POPULATION	8356000	5022000	3334000	121000
11. TESTS/1000 POPULATION	1.86	1.66	2.16	2.64

below 0.14% BAC in the population from 10% states than in that from 15% states.

Two: In the two populations the proportion of persons having BAC's less than 0.09% is no different in states having 0.10% presumptive limit than in states having a 0.15% presumptive limit.

Hypothesis two was rejected at the 99.9% probability level. This means that the chance of erroneously rejecting the null hypothesis, if it were true, is 1 in 1000 or less. The data show a greater proportion of cases falling below 0.09% BAC in the population from 10% states than in that from 15% states.

Three: In the two populations the proportion of persons having BAC's less than 0.04% is no different in states having a 0.10% presumptive limit than in states having a 0.15% presumptive limit.

Hypothesis three was *not rejected* at the 99.9% probability level.

Four: In the two populations the proportion of persons displaying BAC's of *0.24% or greater* is no different in 10% states than in 15% states.

Hypothesis four was rejected at the 99.9% probability level. This means that the chance of erroneously rejecting the null hypothesis, if it were true, is 1 in 1000 or less. The data show a greater proportion of cases falling at 0.24% BAC or greater in the population from 15% states than in that from 10% states.

Five: In the two populations the proportion of persons displaying BAC's of 0.29% or greater is no different in states having a 0.10% presumptive limit than in states having a 0.15% presumptive limit.

Hypothesis five was rejected at the 99.9% probability level. This means that the chance of erroneously rejecting the null hypothesis, if it were true, is 1 in 1000 or less. The data show a greater proportion of cases falling at 0.29% BAC or greater in the population from 15% states than in that from 10% states.

Six: In the two populations the mean of BAC's of all persons tested is no different in states having a 0.10% presumptive limit than in states having a 0.15% presumptive limit.

Hypothesis six was rejected at the 99.9% probability level. This means that the chance of erroneously rejecting the null hypothesis, if it were true, is 1 in 1000 or less. The population from 10% states has a lower mean BAC (0.192%) than that from the 15% states (0.205%).

Discussion

Several observations can be made about comparisons between the BAC distributions and statistics from the two groups of states. (Refer to Table I.) The proportions of the distributions less than 0.04% are not statistically different. This is somewhat reassuring because it seems clear that police officers ordinarily will not be apprehending people with BAC's in this range no matter what the presumptive limit happens to be.[2] Presumably, drivers in this BAC category seldom will be called to the attention of the police by erratic driving practices. On the other hand, some police agencies routinely request that all drivers in crashes submit to tests. Because this procedure could lead to a large group of 0.00% results (no alcohol content), which could bias the data, readings of 0.00% were left out of the distributions and analyses. As a matter of fact, leaving in the 0.00% readings produces a statistically significant difference in the two distributions below 0.04%. For the reason stated above, leaving them out is believed to produce a more reliable result.

Beginning at low BAC's, the cumulative percentage of test results in the 10% states is larger than in 15% states until very high BAC categories are reached. This means that a relatively greater number of moderately intoxicated drivers is arrested in 10% states than in 15% states. As previous discussions stated, the difference between the two sets of data in that regard was statistically significant for BAC's below 0.09%. One possible explanation for the difference is that law enforcement officers are more diligent in apprehending less drunk drivers because of the greater possibility of achieving a conviction under a 0.10% presumptive limit than is enjoyed by enforcement officers under a 0.15% limit. As mentioned before, other factors could explain the result.

Note, that the absolute percentage of arrests between 0.15% through 0.24% is very close to equal in the two distributions. This may suggest that the parent populations from which the two sample distributions are drawn are similar in that region. Most persons would be likely candidates of arrest no matter what the presumptive limit might be.

Note, further, that the absolute percentages in the categories above 0.24% are substantially

[2] At least two exceptions to this assertion should be noted, both involving situations in which gross intoxication should occur at low BAC's. One is the effect of alcohol on inexperienced drinkers, especially young drinkers, who sometimes are strongly affected at low BAC's. The other is joint alcohol-drug intoxication (not necessarily illicit drugs). Although drug induced or exacerbated intoxication has not been noted as a causative component in a substantial proportion of crashes or arrests, the potential exists.

greater in the 15% states than in the 10% states. Several explanations can be offered. One is that since the 10% distribution is heavier proportionately in the lower tail, then the 15% distribution must be heavier somewhere else. Yet, it can be argued that the upper tail should not be disturbed because law enforcement officers surely would not stop apprehending grossly drunk drivers merely because they apprehend more less-drunk drivers. A second explanation is that absolutely more offenders are apprehended in the 10% states (that is, all that would otherwise be apprehended if the limit were 0.15% plus more less-drunk drivers) and, because of that, fewer drunk drivers are allowed to reach the grossly drunk stage before being picked up. Furthermore, more tests (absolutely and proportionately) are refused in 10% states than in 15% states, leaving open the possibility that proportionately more grossly drunk drivers in 10% states are refusing the test. Adding the several factors together produces plausible, but speculative, explanations for the differences in the distribution. They are plainly conjecture, however, and not proof. Nevertheless, in examining arrest rates it is useful to observe that if the experience reported in 10% states (7202 tests from a population of 3.3 million) were to carry forward proportionately in 15% states (5.76 million population), then 12,600 tests would be reported from 15% states. Only 8322 were actually reported. Hence, a lower presumptive limit is associated with a higher arrest rate in these data. This is also shown by parameter 11 of Table I.

Although the two distributions under study are significantly different in the respects discussed, the data from the individual states that were lumped to make them up are not homogeneous. In testing the various hypothesis described in the earlier section of this paper, each individual distribution was tested against the distribution of data from other states with the same presumptive limit lumped together. To illustrate, the distribution of data from 10% state #1 was tested against the distribution of data from the other seventeen 10% states lumped. In every series of tests such as that, the hypothesis under test was rejected about half the time. This suggests that a large amount of variability exists among data from states with the same presumptive limit. It casts doubt upon any assumption that other factors (than presumptive limit) are uniform throughout the various states.

These data and analyses will suggest to some that a lower presumptive limit (0.10% rather than 0.15%) somehow has a causal relationship to the arrest of more less-drunk drivers (that is, BAC's less than 0.14%).[3] The mean BAC of the 10% states is 0.012% lower than that of the 15% states, which is a statistically significant difference, and the proportions of these tested who have BAC's less than 0.14% and less than 0.09% are significantly greater. Notwithstanding that, no causal relationship has been proved. In order to make an inference of a causal relationship with confidence one would need to show that all other factors affecting the data did not account for the observed differences. For example, one would need to show that difference in neither the BAC distributions of the driving populations at risk to arrest nor the law enforcement and testing practices produced the different results in the two sets of data. That has not been shown here. Nevertheless, an association has been shown in these data between lower presumptive limits and a greater proportion of less-drunk drivers arrested, giving some additional credibility to the intuitive argument that such an association should exist.

[3] The data from Utah, a 0.08% state, seem to suggest that lowering the limit to 0.08% would continue to produce differences of the kind seen here. The Utah data are so few and the state's population may be so different in the use of alcohol that comparative analyses on the basis of information now available would not be reliable.

Appendix A

PARTICIPATING CITIES

10% States	Number Tests	Mean	15% States	Number Tests	Mean
Fairbanks, Alaska	283	0.172	Montgomery, Alabama	99	0.195
San Jose, California	982	0.218	Tuscon, Arizona	611	0.173
Denver, Colorado	785	0.196	Hartford, Connecticut	18	0.241
Orlando, Florida	529	0.189	Honolulu, Hawaii	257	0.188
Springfield, Illinois	78	0.184	Evansville, Indiana	161	0.207
Des Moines, Iowa	50	0.202	Topeka, Kansas	65	0.205

PARTICIPATING CITIES—*Continued*

10% States	Number Tests	Mean	15% States	Number Tests	Mean
Lexington, Kentucky	450	0.203	Baltimore, Maryland	730	0.197
Baton Rouge, Louisiana	136	0.182	Brockton, Massachusetts	73	0.187
Minneapolis, Minnesota	1569	0.179	Grand Rapids, Michigan	427	0.198
Omaha, Nebraska	267	0.192	Jackson, Mississippi	514	0.182
Raleigh, North Carolina	342	0.192	Columbia, Missouri	580	0.169
Fargo, North Dakota	52	0.215	Las Vegas, Nevada	203	0.216
Erie, Pennsylvania	94	0.210	Concord, New Hampshire	43	0.206
Warwick, Rhode Island	241	0.207	Trenton, New Jersey	66	0.225
Columbia, South Carolina	497	0.169	Albuquerque, New Mexico	349	0.214
Knoxville, Tennessee	286	0.192	Akron, Ohio	361	0.212
Spokane, Washington	451	0.185	Tulsa, Oklahoma	661	0.205
Charleston, West Virginia	110	0.208	Portland, Oregon	923	0.205
			Dallas, Texas	2025	0.232
			Roanoke, Virginia	133	0.230
			Green Bay, Wisconsin	23	0.205

Note 1: Ogden, Utah participated as representative of the sole 8% state.

Note 2: Among the cities supplying data that were excluded from the study were: Spartanburg, South Carolina, Charleston, South Carolina, Sioux Falls, South Dakota, and Casper, Wyoming (all because data were from 1970 rather than target year of 1969); Ft. Smith, Arkansas (testing practice excluded a number of tests from the records); Washington, D.C. (data suggested that target population was much different from other cities); and Macon, Georgia (data suggested that enforcement practices were much different from other cities).

Appendix B

Statistical Testing Scheme and Statistics

Let: $p_1 = P\,[BAC \leq X]$, for a person tested in a 10% state

$p_2 = P\,[BAC \leq X]$, for a person tested in a 15% state

n_1 = number people tested in 10% state

n_2 = number people tested in 15% state

y_1 = number people tested in 10% state with $BAC \leq X$

y_2 = number people tested in 15% state with $BAC \leq X$

Then: $\hat{p}_1 = y_1/n_1$

$\hat{p}_2 = y_2/n_2$

Null hypothesis: $\hat{p}_1 = \hat{p}_2$ (i.e. proportions are the same)

Using normal approximation technique (valid for n_1 and n_2 larger than 50), one can show that the variance of the difference, $\hat{p}_1 - \hat{p}_2$, is:

$$\text{Var}\,(\hat{p}_1 - \hat{p}_2) = \frac{\hat{p}_1\,(1 - \hat{p}_2)}{n_1} + \frac{\hat{p}_2\,(1 - \hat{p}_2)}{n_2}$$

Then, S.D. $= \sqrt{\text{Var}}$, and,

$$Z = \frac{(\hat{p}_1 - \hat{p}_2)}{\text{S.D.}}$$

For a 2 tail test, the values of Z have the following significance:

For $Z = 1.96$, $X = 0.05$, meaning that if the null hypothesis were true, a Z as large or larger than indicated would be expected to occur by chance no more than five times out of a 100.

For $Z = 2.58$, $X = 0.01$, meaning that if the null hypothesis were true, a Z as large or larger than indicated would be expected to occur by chance no more than 1 time out of a 100.

For $Z = 3.3$, $X = 0.001$, meaning that if the null hypothesis were true a Z as large or larger than indicated would be expected to occur by chance no more than 1 time out of 1000.

The computed value of Z for various values of X, where $BAC \leq X$, (BAC) are shown in the table below:

$n_1 = 7202$ (10% states); $n_2 = 8322$ (15% states)

X	y_1	y_2	Z
0.04	76	76	0.892
0.09	336	277	4.219
0.14	1231	956	9.924
0.19	3217	3032	10.446
0.24	5450	5760	9.030
0.29	6745	7488	8.414
0.34	7089	8155	2.062
0.39	7180	8303	−0.924
0.44	7197	8317	−0.228
0.49	7200	8322	−1.415