Grand Rapids Effects Revisited: Accidents, Alcohol and Risk

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ABSTRACT

Risk analysis is based on information collected about both exposure to danger and the dangerous event itself. In the case of alcohol-related accident risk, information is needed about the prevalence of driving under the influence of alcohol (DUI) and the frequency with which DUI drivers are involved in accidents. These requirements were met in Borkenstein et al.'s Grand Rapids Study. However, one shortcoming of that study was the risk of causing an accident (rather than just being involved in an accident) had to be estimated because the authors did not know whether the driver was responsible for the accident. Our 1993 Accident Study collected information about BAC, responsibility for causing the accident, and driver characteristics for all drivers involved in 4,615 accidents. The information about exposure was taken from the German Roadside Survey, which sampled 13,149 drivers in 1993. Using those data, the well-known risk function of Borkenstein et al. was replicated. However, the BAC distribution for drivers involved in an accident but not responsible for it was markedly different from that for the drivers in the Roadside Survey. In calculating risk function, Borkenstein et al. assumed identical distributions for these two samples. It can be shown that the problematic "dip" in the risk function was at least in part caused by this assumption.

INTRODUCTION

Risk analysis is based on information collected about both exposure to danger and the dangerous event itself. In the case of alcohol-related accident risk, information is needed about the prevalence of driving under the influence of alcohol (DUI) and the frequency with which DUI drivers are involved in accidents. Although these requirements were met in Borkenstein et al.'s Grand Rapids Study the study has one shortcoming: The risk of causing an accident (rather than just being involved in one) had to be estimated because the authors did not have information on whether the driver was responsible for the accident. In our Accident Study, which took place in Germany in 1994, we obtained this information directly from the police. All the analyses described below include only those drivers who were responsible for causing the accident. Information about DUI prevalence was obtained from the German Roadside Survey (see Krüger et al., 1995, in this volume). The risk function resulting from our 1994 study is, in general, comparable to that resulting from the Grand Rapids Study. However, important differences were found concerning the steepness of the risk functions. In addition, it is demonstrated that the global risk function has to be differentiated for subgroups of drinking drivers. The impact of measures directed against these drivers is estimated by means of the attributable risk.

METHOD

The German Roadside Survey was conducted in the northern part of Bavaria (Unterfranken, part of the former West Germany), which has approximately 3 million inhabitants. Three components were done from the end of 1992 to the spring of 1994. Drivers were stopped and selected by the police who followed a random sampling plan. At a separate checkpoint, these drivers were interviewed and asked to supply a breath sample. Of those asked for a breath sample, 9128 (94.8%) agreed. The roadside survey oversampled weekends at night to obtain a large proportion of DUI drivers. For a representative picture of the DUI prevalence in Germany, the observations were adjusted using information from a representative study of driving in Germany (KONTIV; see Emnid, 1991).

The Accident Study was also conducted in Unterfranken. We equipped a selected sample of police cars with breath testing devices, under the condition that officers try to obtain breath samples from all accident drivers, whether or not they were suspected of DUI. In 1993 in Unterfranken, data were obtained from 1.968 drivers who were responsible for causing an accident.

The Roadside Survey and the Accident Study differed very much with regard to time of day (night: 20 p.m. to 4 a.m.; day: 4 a.m. to 20 p.m.) and day of week (weekend: Friday night to Monday morning; workday: Monday morning to Friday evening). These differences are reflective of such risk factors as, for example, the higher accident risk during the night. As we were mainly interested in alcohol-related accident risk, we controlled for these variables by applying a second weighting procedure to the data from the Roadside Survey. This two-dimensional weighting (by time of day and day of week) produced identical subject distributions in the two studies with respect to the combination of those two factors.

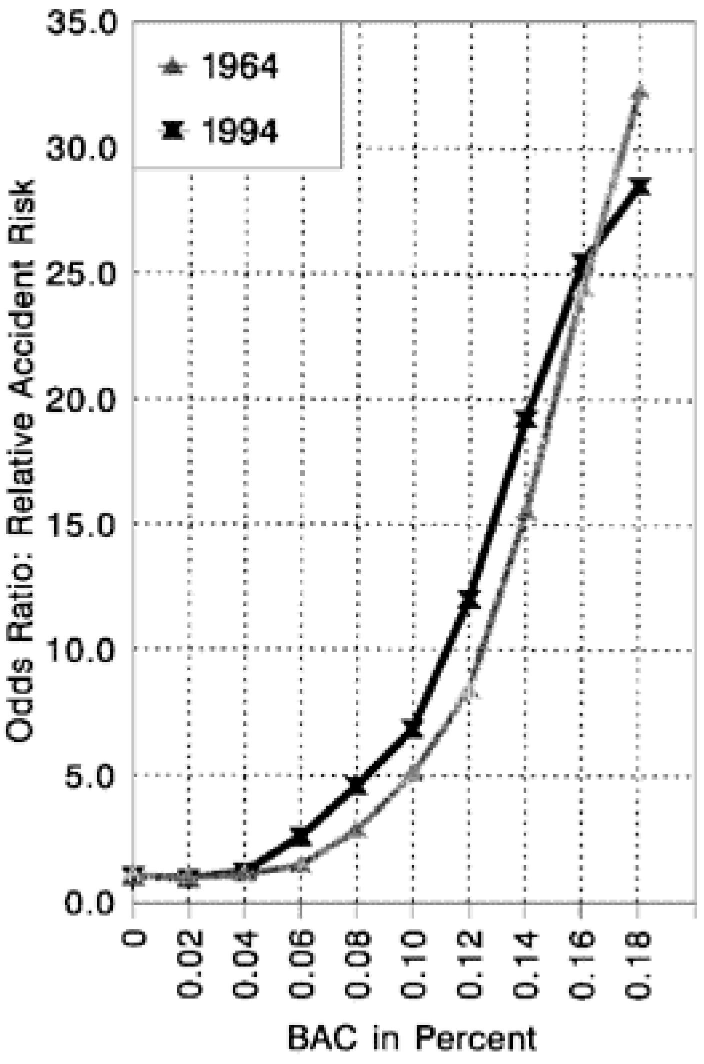
The alcohol-related accident risk is estimated by computing odds ratios. An odds ratio gives a good estimation of the relative accident risk for drivers in a certain BAC class compared to sober drivers (their risk is set to 1). A value larger than 1 indicates an increase in accident risk due to alcohol.

RESULTS

Risk Functions in 1964 and 1994

In 1964, Borkenstein et al. presented the well-known risk function for drivers responsible for causing an accident, which was one basic argument for setting BAC limits in different countries (for example, Germany). Figure 1 shows this risk function compared with the function computed from the Accident Study (both functions were smoothed). The shape as well as the magnitude of the functions are very similar. For drivers with blood alcohol concentrations (BAC) up to 0.04%, the alcohol-related accident risk is nearly identical to or even less than that for sober drivers. Both studies found that, for drivers at BACs ranging from 0.14% to 0.16%, the accident risk is about 25 times as high as it is for sober drivers. However, for nearly all BACs, the 1994 alcohol-related accident risk in Germany was greater than in 1964, a finding that may be a function of today's more complex traffic situations, which in combination with alcohol cannot be handled adequately anymore. At BACs greater than 0.14%, the deteriorating effects of the intoxication may be so great as to make the differences in traffic conditions irrelevant.

Figure 1
Accident risk functions from Borkenstein et al. (gray line) and from our study (black line). At the abscissa, BAC is given in percent, at the ordinate, the odds ratios are given.



Analysis of factors modifying the alcohol-related accident risk showed driver age to be the strongest mediator (see Vollrath, Krüger & Kazenwadel, 1994; Krüger, Kazenwadel & Vollrath, 1995). The global accident risk for drivers between 18 and 24 years is much greater than that for older drivers. In addition, the alcohol-related accident risk for those young drivers increases much faster than it does for older drivers. In light of these findings, we strongly recommend lowering the BAC limit for younger drivers.

The Attributable Risk

Although drivers under the influence of alcohol are obviously at a greater relative risk than unintoxicated drivers, the magnitude of the risk to the larger community attributable to the presence of intoxicated drivers remains an unanswered question. In the German Roadside Survey, only 5.5% of all drivers were found to have BACs greater than 0. Thus, drivers in Germany are exposed to the increased accident risk due to DUI in only 5.5% of their trips (this statement is valid because of the representative weighting procedure described above). By combining the information about the distribution of exposure (DUI) with the estimate of alcohol-related accident risk, one can determine the degree to which accidents can be explained by DUI. This question is adressed by the measure of the attributable risk (for an overview, see Breslow & Day, 1980; Kahn & Sempos, 1989). The basic idea of attributable risk is that some of the accidents involving intoxicated drivers are not due to the effects of alcohol but are the result of the global accident risk also present for sober drivers. This means that the number of accidents involving intoxicated drivers is adjusted to allow for this global accident risk, yielding an excess number of accidents which are attributable to the effects of alcohol.

There are two definitions of attributable risk (AR), addressing two different aspects: (1) The attributable risk for exposed persons (Cole & MacMahon, 1971) renders an estimate of the proportion of all accidents with intoxicated drivers that is attributable to the effects of alcohol. (2) The attributable risk for the population (first described by Levin, 1953) renders an estimate of the proportion of all accidents (including those with sober drivers) that is due to the effects of alcohol.

To compute these ARs, we chose the BAC classes given in Table 1. The first column shows the number of drivers from the German Roadside Survey according to BAC class, and the second column the number of drivers from the accident study. The first step in computing the number of accident-involved drivers within each BAC class attributable to the effects of alcohol (excess) is to compute a factor k of accident involvement for sober drivers. This factor is calculated as:

$k = 1638 / 8438 = 0.1941$

Using this factor, the number of drivers that would be expected to be responsible for causing an accident is estimated for each BAC class. For example, for a BAC greater than 0.20%, 10 drivers were found in the Roadside Survey. Multiplying this number by k results in $10 * 0.1941 = 2$. Thus, we would expect 2 drivers to be found in the Accident Study in this BAC class (not due to alcohol). However, 64 were found yielding an excess number of 62 accidents which may be attributed to the effect of alcohol. Those excess numbers are given in the third column of Table 1. Of course, there are large difference among the BAC classes. At lower BACs, we even find negative numbers indicating the "dip" in the risk function for lower BACs first described by Borkenstein et al. (1964).

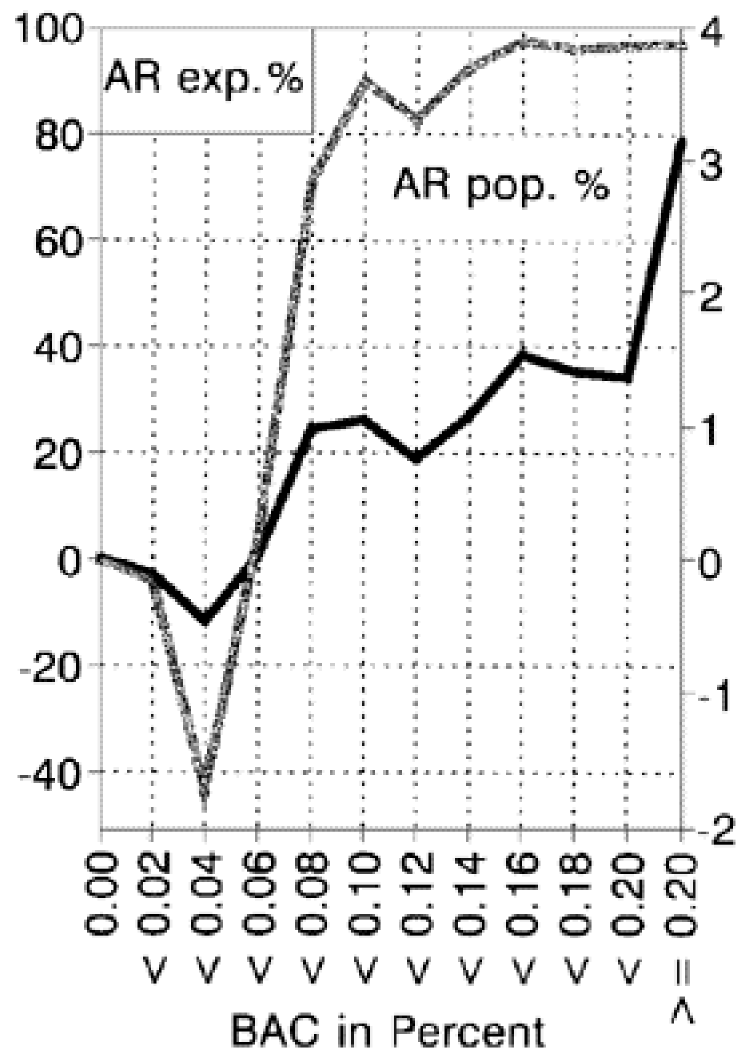
Table 1
Number of drivers in the Roadside Survey and the Accident Study in the different BAC classes. For the computation of the excess number of accidents, see text.

BAC classes	Roadside	Accident	Excess
0	8438	1638	0
< 0.02	284	53	-2
< 0.04	155	21	-9
< 0.06	64	13	1
< 0.08	40	27	19
< 0.10	12	23	21
< 0.12	16	18	15
< 0.14	9	23	21
< 0.16	4	31	30
< 0.18	6	29	28
< 0.20	5	28	27
>= 0.20	10	64	62
Sum	9043	1968	213

For all BAC classes above 0%, we found 330 drivers in the accident study. Of those accidents, 213 were attributable to the effects of alcohol. By dividing those two numbers, we obtain an AR for exposed persons of 213/330=0.65 or 65%. That means, 65% of all accidents involving an intoxicated driver can be attributed to the effects of alcohol. However, in only 16.8% of all accidents (or 330 accidents) was the driver intoxicated. To determine which proportion of all accidents are attributable to the effects of alcohol, the population AR should be computed. This is done by dividing the excess accidents by the total number of all accidents, that is, 213/1968=0.108. Thus, 10.8% of all accidents may be attributed to the effects of alcohol.

Figure 2 gives both ARs computed for different BAC classes. The AR of exposed drivers indicates for each BAC class the percentage of accidents attributable to alcohol. For BACs less than 0.06%, the AR is small, even negative. Hardly any accidents involving drivers with those BACs can be attributed to intoxication. This changes dramatically for BACs greater than 0.06%. At BACs less than 0.08% but greater than 0.06%, about 70% of all accidents are due to alcohol. For all BAC classes greater than 0.08%, the ARs are greater than 80%. For drivers in this latter BAC categories, nearly all the accidents may be attributed to the effects of alcohol.

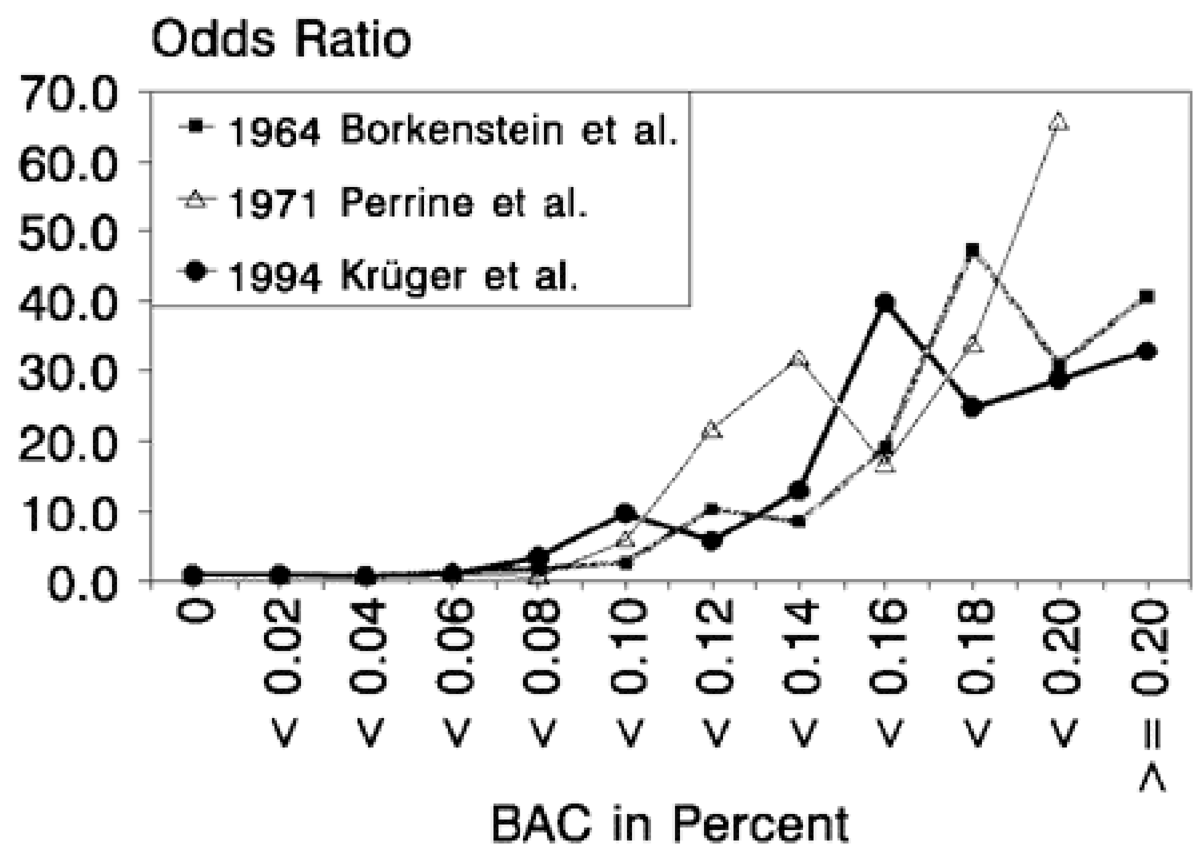
Figure 2
Attributable risk for the exposed drivers (left ordinate, gray line) and the population (right ordinate, black line) in each BAC class. Both risks are given in percentages.



The AR of the population indicates the magnitude of those alcohol effects in relationship to the total number of accidents occuring. The population ARs can be interpreted as follows: If no drivers with BACs greater than 0.20% were present in traffic, 3% of all accidents would not happen. Adding these percentages for all BAC classes gives the 10.8% of all accidents which are due to alcohol. About a third of these accidents can be attributed to drivers with BACs greater than 0.2%.

As Figure 3 shows, this population AR gives a good indication of the effectiveness of measures directed against DUI. In this Figure, the 10.8% accidents were set to 100%. Had no DUI drivers been present in traffic, none of these accidents would have occured, which would have resulted in a 100% reduction. If no one with a BAC greater than 0.08% drove, a reduction of 96% would result. Thus, if the legal limit for DUI in Germany (0.08%) was an effective deterrant against driving with a higher BAC, this would mean that nearly everything that could be done to prevent alcohol-related accidents would have been accomplished. Thus, countermeasures directed at those persons driving at BACs higher than 0.08% can be expected to be most effective in reducing the number of accidents attributable to the effects of alcohol. In contrast, measures directed at drivers with BACs less than 0.08% cannot be very effective. At most, 4% of all accidents attributable to the effects of alcohol may be prevented.

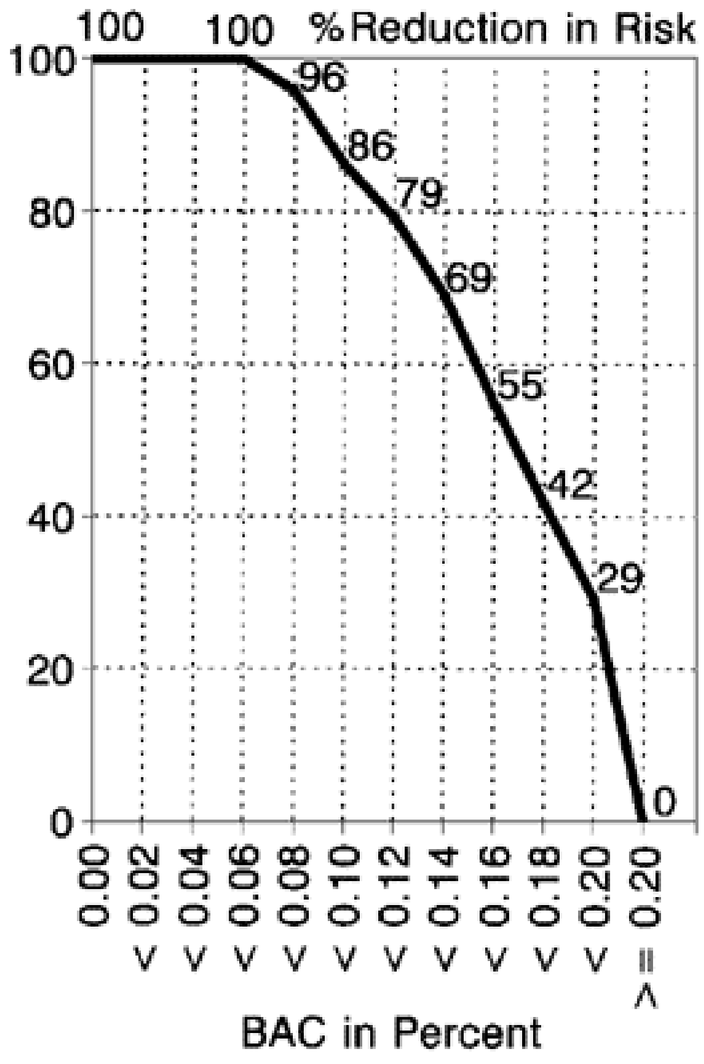
Figure 3
Risk functions for our Accident Study (circles, black line), for the Grand Rapids Study (squares,gray line) of Borkenstein et al. (1964), and for a study by Perrine et al (1971; triangles, thin line)



Sub-Groups Included in the Risk Function

The question remains how to indentify the characteristics of the these drivers with BACs greater than 0.08%. Is driving with high BACs done very seldom by nearly all drivers or is it done quite often by a small subgroup of drivers? We can begin to answer this question be analyzing the risk functions in Figure 1 in detail. These smoothed functions give the impression that alcohol-related accident risk increases monotonically. However, if smaller BAC classes are selected and BAC is truncated at 0.18%, the picture changes. In Figure 4, odds ratios were computed for BAC classes of 0.02%. The risk functions are shown from our Accident study, from the Grand Rapids Study (drivers responsible for the accident), and from a study by Perrine, Waller & Harris (1971) of fatally injured drivers.

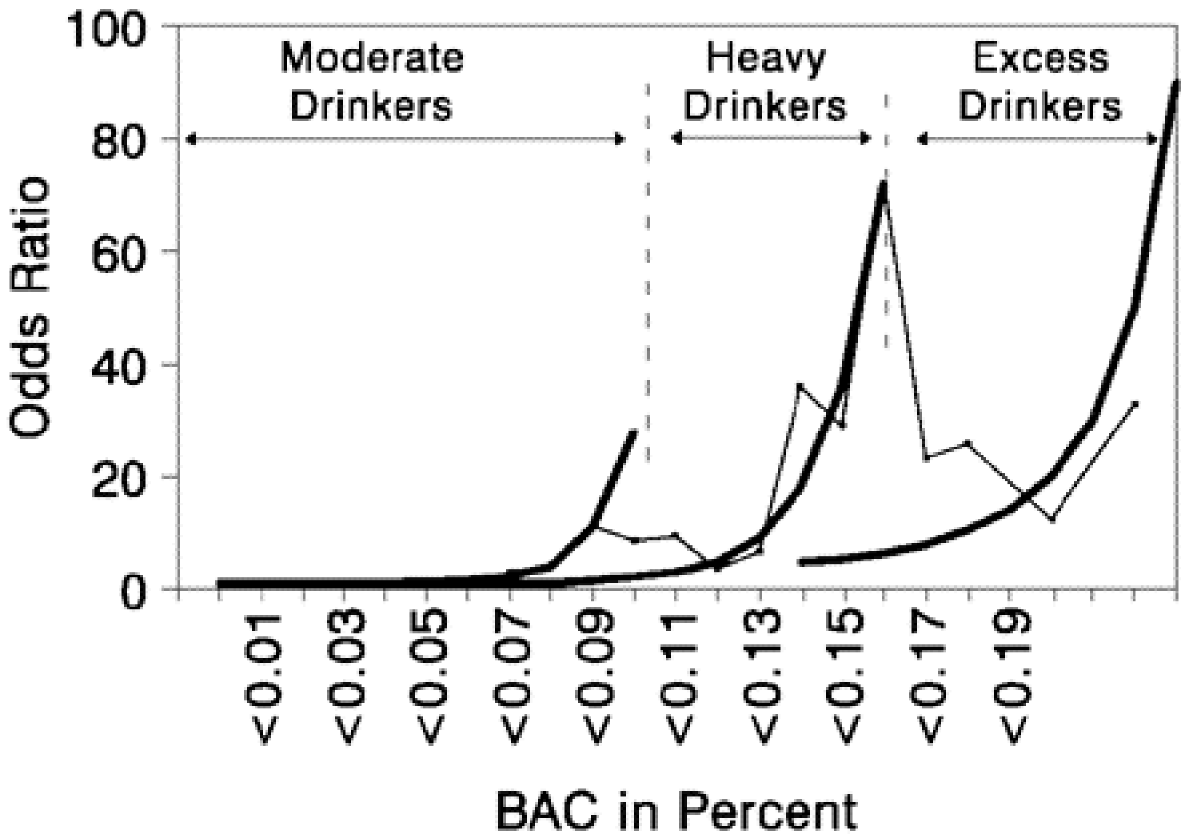
Figure 4
Percentage reduction in alcohol-caused accidents if no drivers at BACs higher than the ones given were present in traffic



Although the studies were done at different times in different countries, the similarities in the structures are striking. In none of the three risk functions is there a monotone increase in risk, but different peaks are found. In our Accident study, the first (small) peak is present between 0.08% and 0.10%, a second peak at 0.14% to 0.16% and a third peak at BACs greater than 0.20%. In the Grand Rapids Study, similar peaks are found but are shifted towards higher BACs. This reflects the finding shown in Figure 1 that, in our Accident Study, the alcohol-related accident risk is higher than that found by Borkenstein et al. (1964). In contrast, in Perrine et al.'s study, the peaks are shifted towards lower BACs, which makes sense as only fatally injured drivers (very serious accidents yielding a larger alcohol-related accident risk) were examined.

The occurence of those peaks in three different studies from different countries and different years suggests that the overlay of risk functions of different sub-populations produces the typical shape of the overall risk function. Extended studies on drinking behavior indicate that three different groups of drinkers may be responsible for the peaks. These hypothesis is supported by studies on hardcore drinking drivers (for example, Simpson & Mayhew, 1993). The assumption of three sub-groups of drinkers is indicated in Figure 5 (the risk function here was computed from our data for BAC classes of 0.01%). The first group consists of moderate drinkers who will never exceed a maximum BAC of around 0.10% (consumption limit). At higher BACs, this group cannot compensate the effects of alcohol very well, which yields the first peak of the risk funktion. Two groups of heavy drinkers are responsible for the other peaks. Both groups have probably developed a certain amount of alcohol tolerance, enabling them to compensate for the effects of alcohol at higher BACs.

Figure 5
Hypothetical sub-populations of drinkers responsible for the peaks in the alcohol-related accident risk function (thick lines). The thin line represents the empirical risk function.



DISCUSSSION

Our Accident Study replicated the well-known risk function of Borkenstein et al. (1964). The comparison indicates that driving under the influence of alcohol resulted in a greater accident risk in 1994 compared to 1964. Considering the incidence of DUI, it was argued that effective countermeasures that substantially reduce the number of accidents attributable to the effects of alcohol should be directed towards drivers with BACs greater than 0.08%. This also implies that simply changing the legal DUI limit from 0.08% to 0.05% is insufficient with respect to alcohol-induced accidents as the potential reduction would be only about 4%. Further inspection of the risk function indicates that certain subgroups of drinking drivers are responsible for the alcohol-related accident risk in the higher BAC range. Measures capable of deterring drinking drivers in this range were expected to have a substantial impact on traffic safety, namely, result in a decrease in accident rates.

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Return to Contents
Return to T'95 Home Page