The Effect of Blood Alcohol Concentration on Motorcycle Crash Characteristics

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Abstract

This paper examines differences in accident characteristics and causation at different blood alcohol levels among 372 accident involved motorcycle riders who were tested shortly after they crashed. The subjects were part of a large, prospective, in-depth study of 1082 accident-involved motorcyclists in Thailand in which investigators went to the scene immediately after a crash to collect and analyze evidence in order to determine how the crash occurred. The crash characteristics considered here include those that have been identified as typical of alcohol-involved motorcycle crashes including collision type, loss of control, running off the road, traffic control violations, precrash & crash speeds. The causation factors include primary cause factors and rider attention failures. Approximately 60% of 372 riders tested positive for alcohol. The frequency of inattention just before the crash increased steadily and almost linearly with increasing BAC. However, most other crash characteristics showed a sudden change in the frequency of occurrence near the 50 mg/dL (.05%) level, then remained relatively steady at higher BAC levels. Compared to non-drinking riders, those with BAC $\geq$ 50 mg/dL were more likely to be in single vehicle crashes, more likely to lose control, to run off the road, to be inattentive before crashing and to be the primary or sole cause of their accident. These findings demonstrate that when rider blood alcohol level approaches 50 mg/dL (.05%), the rider becomes a significantly greater threat to himself.

Keywords: Blood alcohol, BAC, BAL, motorcycle, Thailand,

1. Introduction

How much alcohol is too much for a motorcycle rider? What would be a proper legal limit of blood alcohol concentration (BAC) for motorcyclists? At least three studies in the last decade or so have addressed this issue directly, each in different ways.

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Sun et al [1] found that a group of motorcycle riders admitted to the hospital over a one-year period generally had a lower BAC than car drivers admitted during the same time period: a mean of .12% for motorcyclists compared to .18% for car drivers. Also, a smaller proportion of the motorcycle group had a BAC higher than .15%. From this evidence, they inferred that the skills involved in riding a motorcycle may be more vulnerable to the effects of alcohol, so that drinking riders crash at lower alcohol levels.

However, this inference may overlook the fact that motorcyclists are more easily injured than car drivers. A drunken motorcyclist who sideswipes a parked car will probably be injured and require police and ambulance assistance and perhaps hospitalization. An equally drunk car driver who sideswipes a car is likely to be uninjured and may flee the scene to avoid detection – an option not available to most accident-involved motorcyclists. If one assumes that accident severity increases with increasing BAC, then the better protection provided by a car may explain the difference in BAC between hospitalized motorcyclists and car drivers.

Colburn et al [2] used a driving simulator to test experienced motorcyclists at varying levels of alcohol. They found that after drinking, even at a BAC levels well below the legal limit of 100 mg/dL (.10%), their subjects made more total errors on tasks involving defensive and evasive maneuvers and timed riding through specific course. Drinking riders were particularly prone to "running off the road" in the simulator. This latter observation is consistent with a number of studies that have reported a large increase in run-off-road accidents among drinking riders [Kim? Shankar? Ouellet 87, Kasantikul 2002 a&b, Kasantikul Ouellet et al, submitted]

Ideally, something like Borkenstein's famous Grand Rapids study [_?_] is needed to quantify how motorcycle accident risk increases with BAC: a comparison of blood alcohol levels of accident-involved motorcyclists with riders out on the same roads, exposed to the same risks, but who are not in an accident but are simply checked at random for alcohol involvement. Haworth [1997?] attempted to do this in Australia by comparing BAC levels of crash-involved motorcyclists with riders who passed by the accident scene at the same time-of-day and day-of-week as a previously investigated crash. However, her efforts were frustrated because there were so few motorcycles on the road at night when most alcohol-involved motorcycle crashes occur. Too often, no motorcycles at all passed by the site where exposure data were being collected.

The present study takes a different approach to analyzing the effects of alcohol concentration on motorcyclists by identifying the dosage level at which "typical alcohol crash" characteristics emerge. That is, drinking riders are more prone than non-drinkers to get into certain kinds of crashes. These have long been identified as single vehicle crashes, loss of control crashes and running off the road. Drinkers are more likely to be the primary or even sole cause of their crash and are more likely to be inattentive or daydreaming before they crash. They are also less likely to wear a helmet than non-drinkers, more likely to be hospitalized and more likely to be killed [Citations?] But at what alcohol dosage do drinkers begin to differ significantly from non-drinkers on these measures?

The data reported here come from a two-year study in Thailand in which investigators traveled to the scene of a motorcycle accident immediately after it occurred in order to conduct a detailed, in-depth investigation of the crash circumstances. Accident-involved helmets were obtained whenever possible and injury information was obtained in all cases. The study included 1082 accident-involved riders, of whom 372 were tested for alcohol. Those 372 riders are the subject of this study.

2. Methods

2.1 Data collection

The on-scene investigations were conducted by Thai research teams who had received an intensive, 12-week training course that included crash investigation methodology, motorcycle rider injury mechanisms, human factors, motorcycle design and dynamics, motorcycle crash reconstruction and instruction in processing the comprehensive data form. All on-scene investigators were university graduates, primarily in engineering.

Investigation teams obtained crash notifications by monitoring police radio communications at local hospital or ambulance dispatch centers. Notification occurred whenever police radio transmissions mentioned a motorcycle crash at a location near enough to reach in a timely manner or whenever an ambulance was requested to respond to a motorcycle crash. After notification, an investigation team traveled to the motorcycle crash scene in an emergency vehicle using lights and siren. Once on-scene (usually within 10-30 minutes of the crash), the team divided into groups which photographed the motorcycle(s) and other vehicles involved as well as skids, scrapes, pre-crash paths of travel, etc. Investigators also collected on-scene measurements, driver and witness interviews, injury information and police reports. Investigation teams were on scene while the police conducted their investigation in over 90% of the cases reported here; the remainder was investigated within a few hours. Once the on-scene investigation was complete, the injured parties were followed through the medical system to collect injury information.

Essentially the only criterion for whether a case was included among the 1082 cases in the Thailand study was whether the team was able to get to the crash scene and collect enough information about the crash to have a complete investigation. There was no pre-selection for any particular crash characteristic. In this way, the data avoided biases that can occur when only selected populations are examined, such as police reports, fatalities, hospital admissions, or particular injury types. The additional qualification for reporting in this study of BAL effects is the requirement that the rider’s BAC was measured and known as a result of quantitative testing. Riders who were not tested by measuring a blood, urine or breath sample are not discussed in this report, no matter how obvious their sobriety or intoxication.

A total of 959 collisions involving 1082 riders and 399 passengers were investigated in six different regions within Thailand over a twenty month period. One-fourth of the collisions involved two motorcycles, which is why there were more motorcycles and riders than collisions. The first twelve months were devoted to collecting data in Bangkok (723 cases), and the remaining months involved 359 cases in other “upcountry” sampling regions of Thailand (i.e., the provinces of Phetchburi, Trang, Khon Kaen, Saraburi and Chiang Rai) located 150 to 700 km from Bangkok.

Blood and urine samples were collected on-scene, during transport to the emergency department (ED) or soon after arrival at the ED. If the rider died before blood could be drawn, a sample was taken during the autopsy. Blood samples were submitted to the Department of Forensic Medicine, Chulalongkorn University. Breath analysis was performed by the investigation team using an Alcolmeter SD 400 portable breathalyzer.

In each accident, as many as three contributing factors were ranked in order of their contribution. The first factor listed was considered the primary cause factor. If no second factor was listed then the primary cause was considered to be the sole cause of the accident. A positive BAC test was not necessarily considered a contributing factor to accident causation. For example, if an alcohol-involved-rider was stopped waiting in traffic at a red traffic signal and was struck from behind by another vehicle, then rider alcohol was not regarded as a contributing factor.

The crash investigation and reconstruction methodology used for this study was similar to the methodology used in a previous on-scene motorcycle crash study by Hurt et al., (1981) and has been described elsewhere (Smith et al., 2001). The data form was nearly identical to a recently developed Common International Methodology (OECD, 2001) for on-scene motorcycle accident investigations and contained nearly 3000 data entries. Data elements ranged from simple items such as weather, lighting conditions, motorcycle manufacturer or rider gender to complex factors such as precrash and crash speeds, injury mechanisms and accident cause factors. After investigation and reconstruction of each crash by the Thailand team, all 1082 cases were sent to the Head Protection Research Laboratory in California for additional quality control review. Every case was reviewed individually and changes recommended as needed.

2.2 Statistical analysis

Many of the factors reported here are treated as if they were separate but they actually covary. For example, most single-vehicle crashes are the result of rider error (often inattention) and involve some kind of loss of control, most often by running off the road.

A two-by-two chi square analysis (without correction for discontinuity) was used for most comparisons of drinking riders to non-drinkers. The strategy was to repeatedly iterate the chi-square test, varying the BAC range in order to find the lowest BAC level that showed both a statistically significant difference between drinkers and non-drinkers and no cells with an expected frequency less than five. In each iteration, BAC levels were shifted by 5 mg/dL. Once a BAC range was identified that differed significantly from non-drinkers, higher ranges of BAC were checked to make sure that they too differed significantly from non-drinkers. For some variables tested (such as running off the road) when the comparatively large (n=143) the non-drinking group had 90% - 10% split (or a split even more one-sided) it was very difficult to obtain expected frequencies of five or greater in all cells without using an extremely wide range of positive blood alcohol levels. In those situations, the results of Fisher's Exact Test are reported.

3.0 Results

3.1 BAC distribution

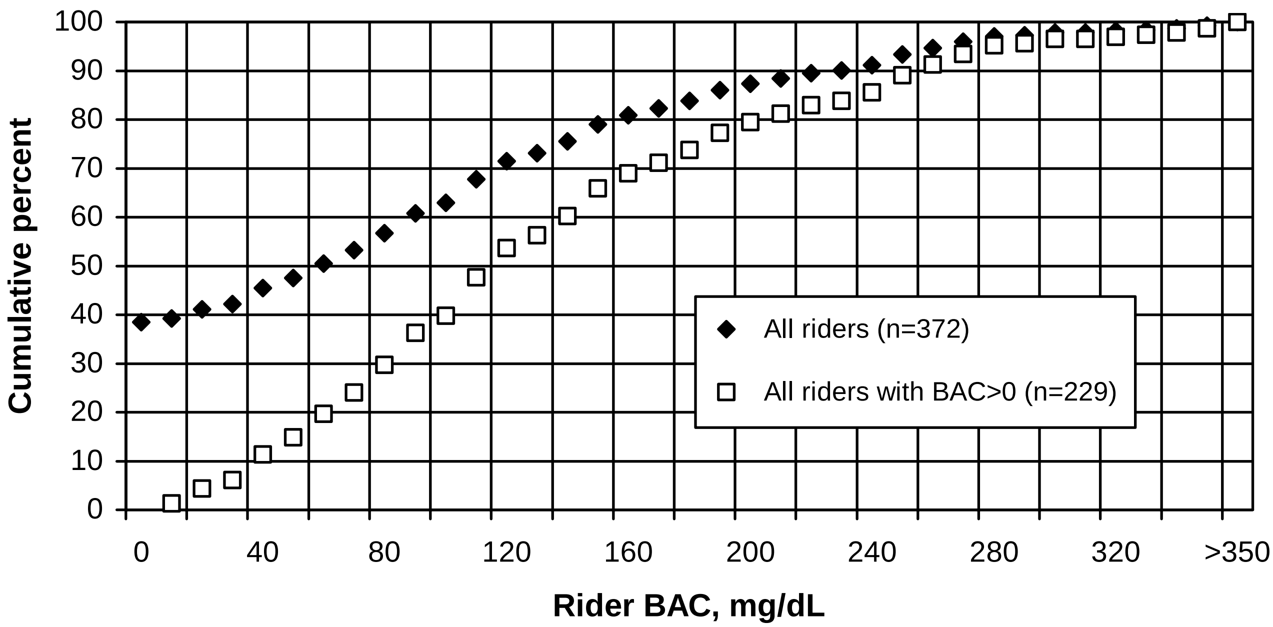
Approximately two-thirds of the riders (252) were tested by means of a blood sample, while 119 (31.9%) were tested by breathalyzer. Two riders gave a urine sample.

Over 60% of the riders tested positive for alcohol. The median BAC among those who tested positive was 113 mg/dL. The 25^{th} and 75^{th} percentile BAC levels were 71 and 185 mg/dL, respectively. Table 1 combines individual BAC concentrations into ranges. Figure 1 shows a cumulative percent distribution for all 372 riders and a second cumulative distribution that includes only the riders who tested positive.

Table 1: Measured blood alcohol concentration (BAC)

BAC, mg/dL, grouped	Tested riders only		
	Frequency	Percent	+ BAC, Cumulative %
None	143	38.3	-
01 – 49	30	8.0	13.1
50 – 79	35	9.4	28.4
80 – 99	26	7.0	39.7
100 - 149	57	15.3	64.6
150 - 199	33	8.8	79.0
200 - 249	22	5.9	88.6
250+	26	7.0	100.0
Subtotal - drinkers	229	61.6	-
Total	372	100.0	-

Figure 1. Cumulative percent distribution of all riders and only those riders with BAC>0.



3.2 Crash type

The type of crash changed as BAC increased, as shown in Figure 2. Motorcycle-solo crashes, loss of control crashes and crashes in which the motorcycle ran off the road in the absence of threat from any other vehicle all changed only slightly for riders with a BAC of 1-49 mg/dL, compared to non-drinkers. However, riders in every BAC group with 50 mg/dL or higher were significantly more likely than non-drinkers to be in single vehicle crashes (Fisher's Exact Test, $p < .032$), more likely to crash by losing control (Fisher's Exact Test, $p < .02$) and more likely to crash by running off the road (Fisher's Exact Test, $p < .025$).

These findings suggest that "alcohol-type" motorcycle accidents begin to occur significantly more often at a BAC somewhere below 80 mg/dL. Successive iterations of the chi-square test using different positive BAL ranges to find the lowest range that differs significantly from non-drinkers suggest that "alcohol-type" crashes become significantly more frequent in a BAC range around 30-70 mg/dL with a median BAL near 50 mg/dL (.05%) for all three variables.

Table 2 compares non-drinking riders to riders in the lowest positive BAC range that differed significantly from non-drinkers on a number of variables. The variables are arranged in order of increasing median BAC. Rider inattention-daydreaming just before the crash was the variable with the lowest BAC at which drinkers differed from non-drinkers. Only 3% of the 143 non-drinkers showed evidence of inattention just before crashing, compared to 27% of the 11 riders in the 20-40 mg/dL range.

Figure 2. Crash type as a function of rider BAC

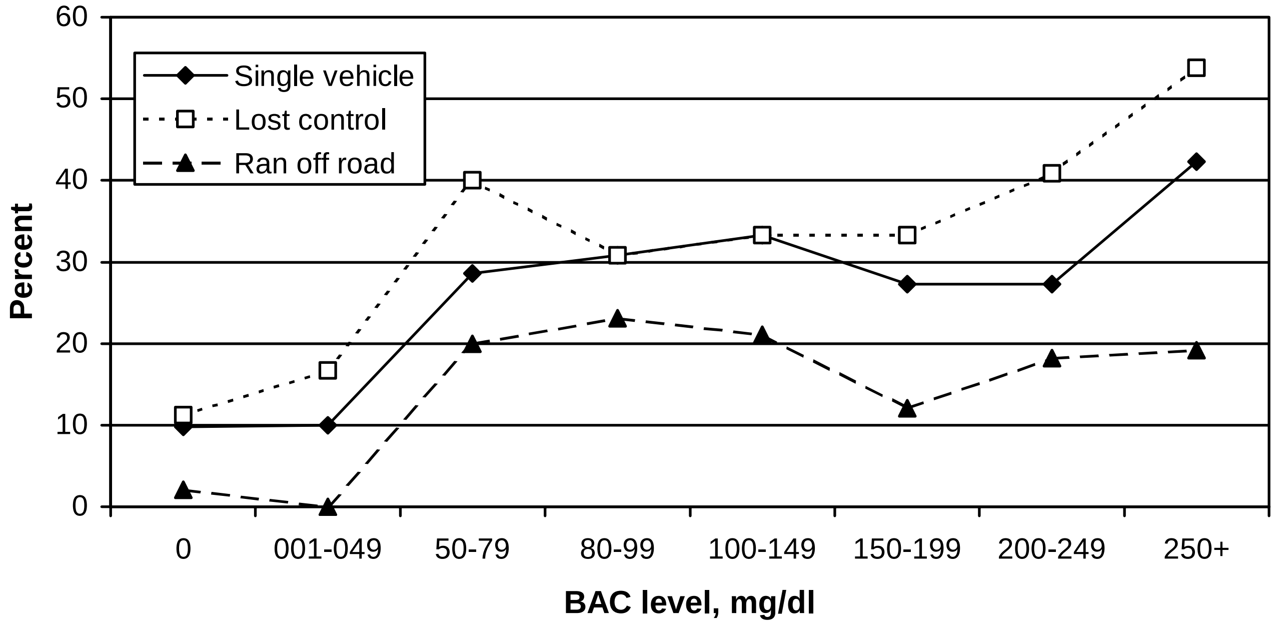


Table 2. Minimum BAC range that differs significantly from non-drinkers for different variables

Variable	%, BAC=0 (n=143)	Group with minimum BAC difference from non-drinkers					
		%, BAC+	BAC range, mg/dL	$n_{drinkers}$	Median +BAC, mg/dL	χ^2	p
Rider inattentive	3	27	20-40	11	31	FET	.010
MC LOC*	11	30	30-50	20	40	FET*	.034
Rider error PCF*	42	65	30-55	26	42	4.868	.027
Struck roadside object	8	23	20-60	35	43	FET	.031
OV err PCF*	53	22	40-60	18	50	5.877	.015
MC solo, yes/no	10	22	30-70	41	51	4.308	.038
MC LOC*	11	39	35-65	33	51	15.32	.000
MC ran off road	2	18	35-65	33	51	FET	.002
Rider error SCF*	17	38	55-80	29	69	6.653	.010
Violated traffic control	34 (n-41)	64	60-100	14	80	3.90	.048

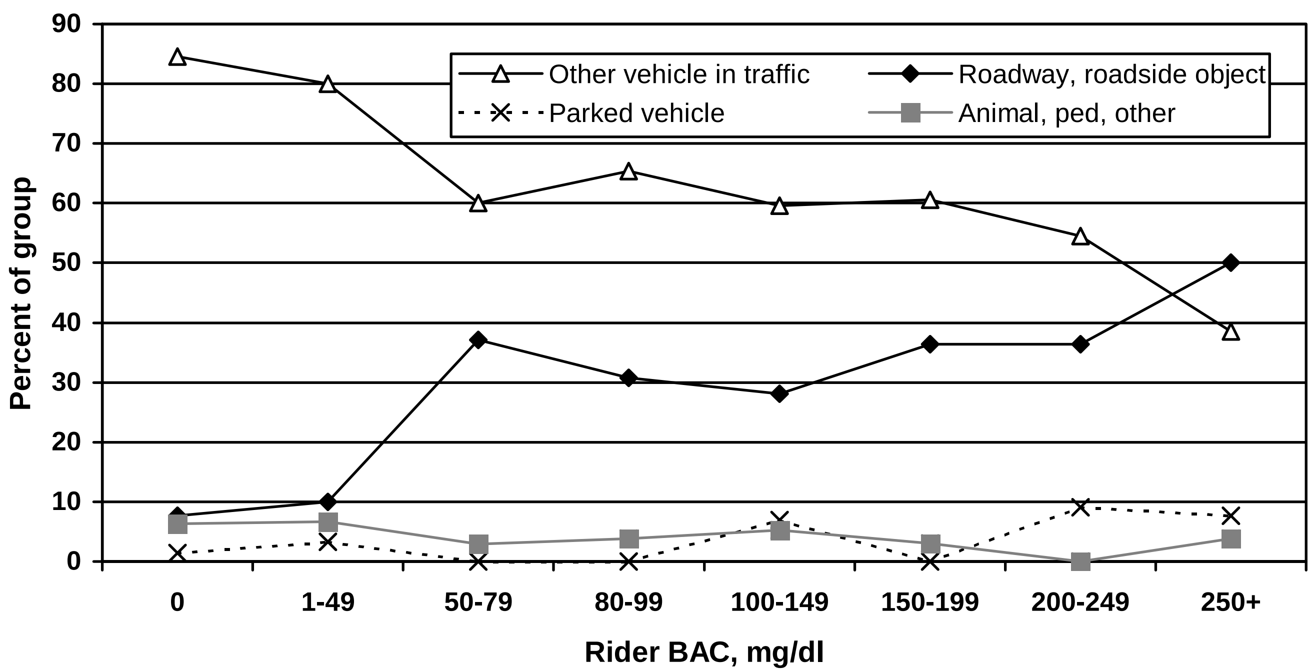
* PCF = Primary cause factor; SCF = Sole cause factor; LOC = Loss of control; FET = Fisher's Exact Test

3.3 Object struck by motorcycle

As rider BAC increased, especially above 50 mg/dL, collisions with roadside obstacles and the roadway itself increased markedly (to an average of 35%), with a commensurate decrease in collisions with other vehicles in traffic. Collisions with pedestrians and animals varied little as a function of rider BAC (varying from 3-7%). Collisions with parked vehicles averaged 7% for riders with a BAC above 100 mg/dL and 1% for riders below that level. The data are shown in Figure 3.

Drinking riders with a BAC as low as 20-60 mg/dL (median 43 mg/dL) were significantly more likely than non-drinkers to collide with the roadway or some roadside object (23% vs. 8%), as shown in Table 2.

Figure 3. Objects struck by motorcycle as a function of rider BAC

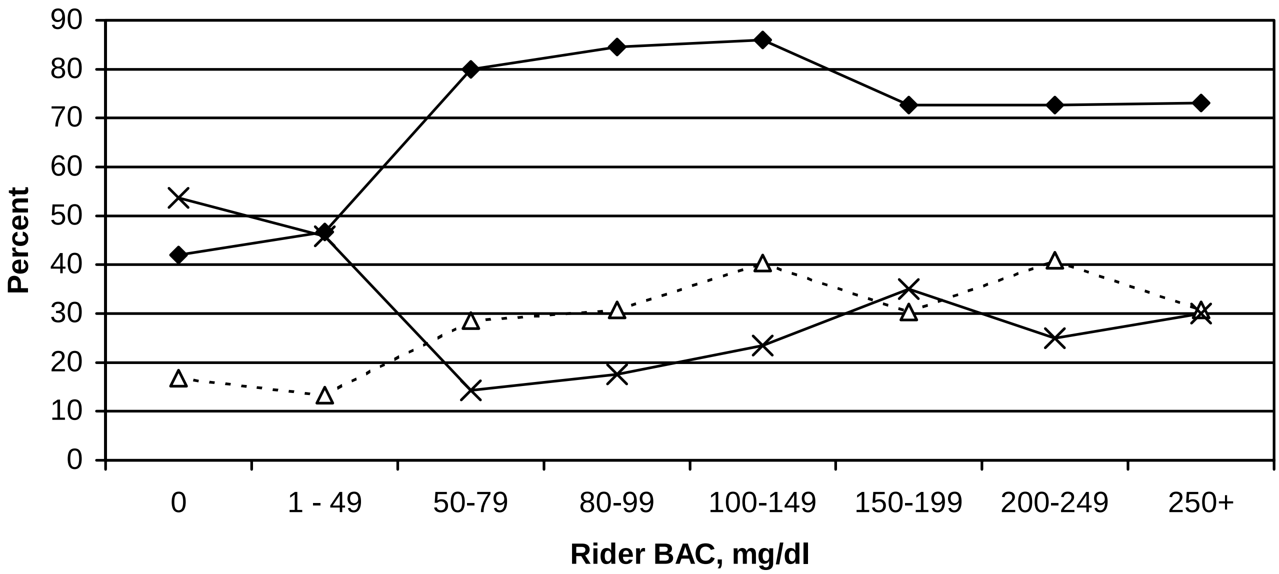


Rider error as the primary cause and as the sole cause of the crash increased, and OV driver error decreased as BAC increased. All three showed a sharp increase in frequency at BACs above 50 mg/dL. Figure 4 compares riders by BAC range on these three variables. In every group of drinkers with a BAC of 50 mg/dL or more, rider error was the primary cause about twice as often as it was among non-drinkers (72-85% vs. 42%). Similarly, in all groups with a BAC $\geq$ 50 mg/dl, rider error as the only cause of the crash was about twice as common as it was among non-drinkers (29-41% vs. 17%).

Conversely, OV driver error decreased slightly in the 1-49 mg/dL group as the primary cause in multiple vehicle crashes, then fell sharply in all groups with a BAC $\geq$ 50 mg/dL. The linkage of rider error and OV driver error is, literally, co-incident: the two factors were the primary cause of 91% of all crashes, so an increase in one as primary cause usually results in a decrease in the other.

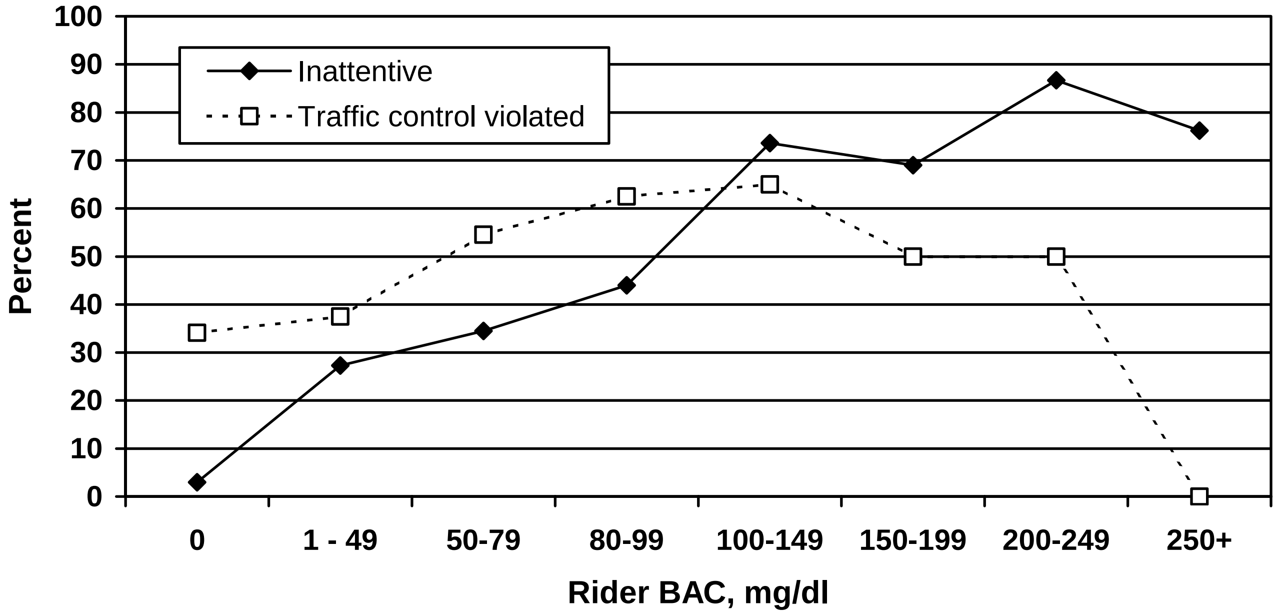
Table 2 shows that riders with a BAC in the 30-55 mg/dL range (median 42 mg/dL) were significantly more likely than non-drinkers to be the primary cause of the crash. Similarly, OV driver error as the primary cause dropped significantly for rider BACs as low as 40-60 mg/dL (median 50 mg/dL) compared to non-drinkers. Riders with a BAC as low as the 55-80 mg/dL range (median 69 mg/dL) were significantly more likely than non-drinkers to be the only cause of their crash.

Figure 4. Accident cause as a function of rider BAC



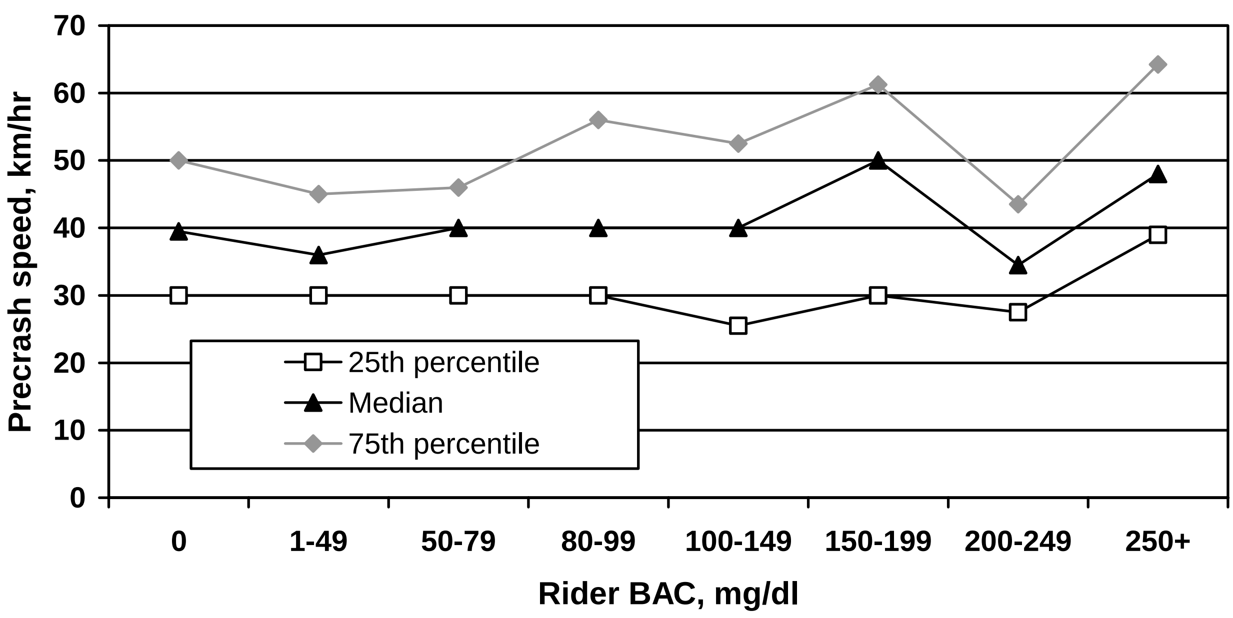
Inattention / daydreaming just before the crash – usually evidenced by a neurologically intact rider's inability to explain what had happened just before a crash – increased rapidly and almost monotonically as BAC rose. Only 3% of the 143 non-drinking riders showed evidence of inattention or daydreaming just before they crashed, compared to 81% of riders with BAC $\geq$ 200 mg/dL. Figure 5 shows that inattention increased dramatically even at low BACs. Riders with a BAC as low as 20-40 mg/dL (median 31 mg/dL) were significantly more likely to be inattentive than non-drinkers (Table 2). On the other hand, while drinking riders, as a group, are far more likely to violate traffic controls (53% vs. 34%; $\chi^2 = 3.63$, p = .057, df = 1), the effect of BAC is not nearly as obvious as it is for inattention in Figure 5. This is partly because so few crashes (105) occurred in the presence of traffic controls and the 64 drinking riders are spread over seven BAC ranges: only one of those seven groups (100-149 mg/dL) has more than 11 riders. None of the three riders with BAC > 250 mg/dL violated a traffic control.

Figure 5: Rider inattention-daydreaming and traffic control violations as a function of rider BAL



Motorcycle precrash speed did not vary significantly as a function of BAL. In fact, speed ranges remained nearly flat across the entire spectrum of blood alcohol levels, as shown in Figure 6.

Figure 6: Motorcycle precrash speed as a function of rider BAL



4. Discussion

The data presented here show a large shift toward “alcohol-type” crashes when rider BAC is approximately 40 - 50 mg/dL (.04% - .05%). Rider attention to the driving task appears to be the factor most susceptible to the effects of alcohol. That is, the inattention or daydreaming so common among drinking riders increased significantly in riders with a BAC as low as the 20-40 mg/dL (median = 30 mg/dL) and increased in frequency almost linearly as BAC increased.

Drinking motorcyclists were far more likely than non-drinking riders to be involved in a single vehicle loss-of-control crash, especially at night, often with the motorcycle running off the side of the road in the absence of interference by any other vehicle. Rider error as the primary or sole cause factor is a major element in alcohol crashes. Rider inattention or daydreaming appears to be a major causal or contributing factor in “alcohol-type” collisions [Kasantikul 2002a, 2002b; Kasantikul et al., 2005; Kim et al., 2000; Ouellet et al., 1987; Shankar, Taiwan guys.]

Only one factor – inattention – showed a nearly monotonic increase in the frequency of occurrence as BAC increased. Most of the other characteristics typical of alcohol-involved crashes – single vehicle crashes, rider error, running off the road, etc. -- rose sharply around 40-50 mg/dL, then remained steady at a higher frequency of occurrence despite increasing BAC. For example, collisions with another vehicle in traffic averaged 84% for riders with BAC < 50 mg/dL, then remained at the 55-60% level for all five BAC groups from 50-249 mg/dL. Similarly, rider error as the primary cause increased from about 43% for riders with BAC < 50 mg/dL, then averaged 84% for riders in the 50-150 mg/dL range and 73% for riders above 150 mg/dL.

The reason for this seemingly asymptotic behavior may lie in the multiple cause factors in traffic accidents. That is, the ability to divide attention between driving tasks (i.e., speed control, lane following, route control, monitoring adjacent traffic, etc.) is affected quite directly by alcohol and this direct affect can be seen in the steady increase in precrash inattention as BAC rises. However, the other characteristics of alcohol-type crashes depend on other situational variables – the actions of other vehicles in traffic, roadway layout & signing, etc. For example, collisions with animals or pedestrians hardly varied as a function of BAC, largely because they are so rare and because riders have such poor prospects of responding adequately when they suddenly encounter an animal or pedestrian in their path. Similarly, even for riders with a BAC above a staggering 250 mg/dL level, 30% of the crashes were caused primarily by OV driver error and another 30% were attributable only to rider error.

At present, no Grand Rapids type study of rider BAC and accident risk is available, so it cannot be proved that accident risk increases markedly at blood alcohol levels in the 40-50 mg/dL range. However, the fact that “alcohol-type” crash characteristics become markedly more frequent in the 40-50 mg/dL range certainly suggest that when a rider’s BAC exceeds 50 mg/dL (.05%) the rider becomes a much greater danger to himself.

5. Acknowledgements

The authors are indebted to the Head Protection Research Laboratory, Paramount, CA, 90723, USA for support in the preparation of this paper.

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