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EVALUATION OF BREATH ALCOHOL PROFILES FOLLOWING A PERIOD OF SOCIAL DRINKING

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ABSTRACT

Ten healthy volunteers (six males, four females) consumed 0.37 to 0.52 g of alcohol per kilogram of body weight per hour over an approximate three-hour period. Each subject provided frequent breath samples into an Intoxilyzer® 5000C breath testing instrument during the drinking session and for approximately four hours following the end of drinking. The blood alcohol concentrations were determined from the Intoxilyzer® 5000C results using a blood:breath ratio of 2100:1. The highest blood alcohol concentrations ranged from 85 to 190 mg% (mean 128 mg%), and were achieved 12 minutes after the end of drinking (range 4 to 22 minutes). The mean time from the end of drinking to the start of linear decline was 69 minutes (range 0 to 124 minutes). The mean alcohol elimination rate was 19 mg%/hr (range 15.4 to 21.7 mg%/hr).

RÉSUMÉ

Dix volontaires en bonne santé (six hommes et quatre femmes) ont consommé entre 0.37 et 0.52g d'alcool par kilogramme de poids corporel par heure durant une période appoximative de trois heures. De fréquents échantillons d'haleine ont été obtenus de chaque sujet et analyzés à l'aide de l'Intoxilizer ®5000C durant la séance de consommation d'alcool et pour une période de quatre heures après la fin de la consommation d'alcool. Les concentrations sanguines d'alcool ont été déterminées à partir des résultats de l'Intoxilyzer tout en utilisant un rapport de sang à haleine de 2100 à 1. Les concentrations d'alcool les plus élevées se trouvaient dans l'écart de 85 à 190 mg% (moyenne de 128 mg%) et ont été observées 12 minutes après la fin de la consommation d'alcool (écart de 4 à 22 minutes). Le temps moyen entre la fin de la consommation d'alcool et le début de son élimination linéaire était de 69 minutes (écart de 0 à 124 minutes). Le taux moyen d'élimination de l'alcool était de 19 mg%/h (écart de 15.4 à 21.7 mg/h).

INTRODUCTION

Under Canadian law, if breath or blood samples are obtained within two hours of an impaired driving offense, the blood alcohol[3] concentration (BAC) at the time of the offense is presumed to be the same as the BAC at the time the samples were taken. If the samples are taken outside this two-hour time period, an alcohol expert witness must attend court to extrapolate the readings back to the time of the offense.

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3. The term "alcohol" refers to ethanol.

The practice of retrograde extrapolation often requires the expert witness to make several assumptions in order to provide an estimate of a person's BAC at some point earlier in time. One assumption that is made is that the individual's elimination rate falls within the range of elimination rates that have been measured in experimental subjects. Other required information includes whether the individual consumed any alcohol between the time of the incident and the time that the samples were taken, as well as information about the individual's drinking pattern prior to the incident. By assessing this information, the expert witness may be able to estimate the individual's BAC at the time of the incident.

In order for the expert witness to be able to assess whether the individual's BAC would have been rising or falling at the time of the incident, the expert must have knowledge about the effects that an individual's drinking pattern would have on the BAC profile. Most of the studies published in the literature which examined the absorption and elimination of alcohol involved drinking situations that do not reflect real-world conditions (1-7). In most of the studies done to date, the alcohol consumption occurred in a bolus fashion, or in a very heavy drinking situation such that the subjects consumed a large amount of alcohol over a relatively short time frame (usually one hour or less). Although these studies provide valuable information with respect to the absorption and elimination of alcohol, they may not reflect what happens to a person's BAC profile following a session of normal, social drinking that extends over a period of hours. A limited number of studies have involved drinking under more real-world conditions (8-12 and 20-23), however, there is a need for more research in this area.

The purpose of this study was to examine the BAC profiles in healthy volunteers following a period of social drinking and to determine whether the profiles are significantly different as compared to heavy or bolus drinking situations. Areas of particular interest are the magnitude of the rise in BAC, if any, after the end of drinking, as well as the duration of the absorption phase of the BAC profile.

MATERIALS AND METHODS

Subjects and conditions

Studies were conducted on ten volunteer subjects (six males and four females). Four subjects were tested on one day and six the following day. Table 1 outlines the personal characteristics for each subject. The mean age of the males was 44 years, mean weight was 94 kilograms and mean height was 178 centimetres. The mean age of the females was 41

TABLE 1

Subject Personal Characteristics and Type and Amount of Liquor Consumed

Subject	Gender	Age (yrs)	Weight (kg)	Height (cm)	Type of 40% v/v Liquor	Volume Liquor (mL)	Dose (g/kg)	Rate of Drinking (g/kg/hr)
1	M	55	116	180	Whisky	511	1.39	0.52
2	M	54	106	180	Scotch	469	1.41	0.47
3	F	51	70	161	Scotch	313	1.42	0.47
4	M	52	97	185	Scotch	426	1.39	0.46
5	F	40	62	168	Rum	256	1.31	0.44
6	M	31	95	178	Vodka	341	1.14	0.38
7	F	41	63	163	Whisky	256	1.29	0.43
8	F	33	81	185	Vodka	298	1.16	0.39
9	M	46	73	180	Scotch	256	1.11	0.37
10	M	26	76	165	Vodka	298	1.24	0.41

years, mean weight was 69 kilograms and mean height was 169 centimetres. No instructions were provided to the subjects about eating prior to the experiment and so it is assumed that most had consumed breakfast prior to the drinking.

All subjects were weighed and determined to be alcohol-free by means of an Intoxilyzer® 5000C test. Drinking started at 9:00 a.m. and continued for approximately three hours (range 160 to 181 minutes, mean 175). Participants consumed an alcoholic beverage of their choice, with all subjects choosing a 40% (v/v) liquor. Subjects 2, 4 and 9 drank neat scotch; all others diluted their drinks with a mix of their choice. Subjects consumed known amounts of alcohol ranging from 0.37 to 0.52 grams of alcohol per kilogram of body weight per hour, with total amounts ranging from 255 to 510 millilitres of 40%(v/v) liquor over the three-hour period. Subjects were allowed to consume snacks (potato chips, pretzels and peanuts) throughout the duration of the experiment and each ate a light lunch approximately one hour after the end of drinking.

Breath Sampling

Four Intoxilyzer® 5000C (CMI Inc., Owensboro, Ky) breath test instruments were used in the determination of the BACs of the subjects. The BACs, reported in milligrams of alcohol in 100 millilitres of blood (mg%), were estimated by the analysis of breath samples. The Intoxilyzer® 5000C instruments were calibrated using a 2100:1 blood:breath ratio and the calibration of each instrument was verified prior to, during, and after the completion of the experiment using a Guth Laboratories Model 34C simulator containing a solution with an alcohol concentration of 121 mg/100 mL (expected Intoxilyzer® 5000C result of 100 mg%). The mean calibration check result for all instruments was 100 mg% (range 95 to 103 mg%). After the completion of the first and second hours of drinking, the subjects provided at least one breath sample to assess their BAC at that time. Prior to providing these samples, and also at the end of drinking, the subjects rinsed their mouths several times with warm water to speed the dissipation of mouth alcohol. During the first hour following the end of drinking, subjects provided breath samples into Intoxilyzer® 5000C instruments approximately every 5 minutes, and then approximately every 15 minutes for the next three hours. All breath samples from a particular subject were provided into one Intoxilyzer® 5000C instrument.

Evaluation of Blood Alcohol Profiles

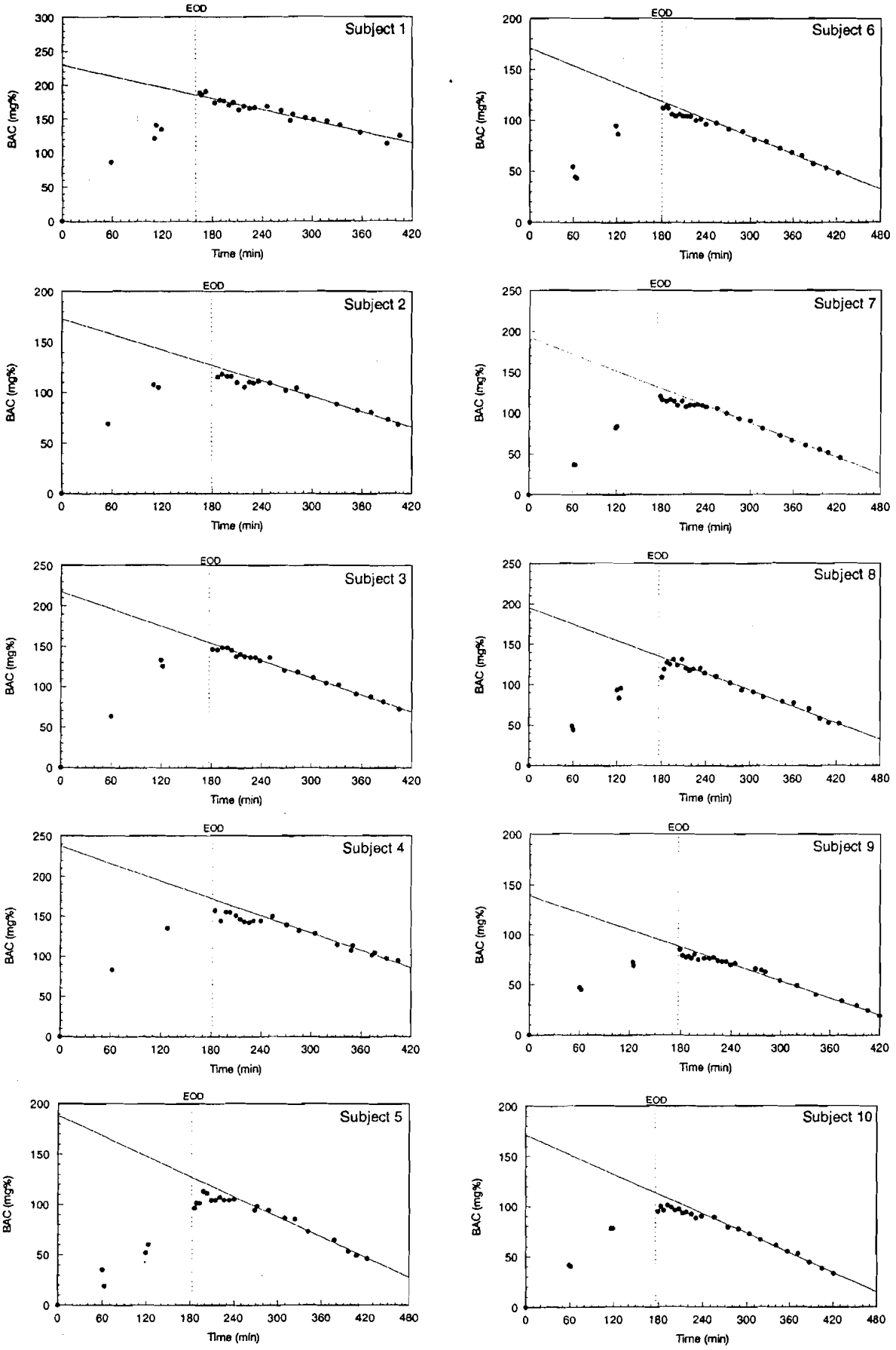
BAC profiles were plotted for each subject (Figures 1 to 10) and the data are summarised in Table 2. In the figures, EOD refers to the end of drinking. The highest BAC

TABLE 2

Blood Alcohol Parameters Derived From the BAC Profiles (Figs. 1 to 10)

Parameter	Mean	Std. Dev.	Range
Highest BAC measured (mg%)	128	30	85 – 190
Time to highest BAC from EOD (min)	12	6.5	4 – 22
Highest BAC - BAC of first sample after EOD (mg%)[1]	5	7.7	0 – 22
Graphical Co (mg%)	192	30	139 – 238
Time from EOD to start of linear decline (min)	69	33	0 – 124
Elimination rate (mg%/hr)	19.0	2.3	15.4 – 21.7

[1] The mean time from the EOD to the first BAC was 5.1 min. (Range 3 - 9 min.)



Figures 1-10. BAC profiles of the ten subjects. The BACs in mg% were determined by the Intoxilyzer® 5000C. The time is from the start of drinking. EOD refers to "end of drinking".

measured and the time of its occurrence was determined. A regression analysis was conducted on the portion of the BAC profile exhibiting a rectilinear decline with the highest correlation coefficient (i.e. closest to 1.0). The correlation coefficients for subjects 2 to10 exceeded 0.99. The correlation coefficient for subject 1 was 0.973. The first point on this portion of the BAC profile was taken to be the start of the linear decline. The elimination rate was determined by the slope of the regression line. A mean of 12 readings (range 7 - 23) over a mean time period of 167 minutes (range 121 - 240) was used in the determination of the elimination rate of each subject. The rise, if any, in each subject's BAC after the end of drinking was noted.

The theoretical maximum BAC (graphical Co) for each subject was determined by the y-intercept of each graph. The theoretical maximum BAC refers to the theoretical BAC achieved if all the alcohol that was consumed was to be totally absorbed and distributed throughout the body instantaneously. Co values were calculated for each subject using the original Widmark formula (13), as well as the updated Widmark formula developed by Watson (14). Since the original Widmark formula was based on pro mille (wt/wt) units, the specific gravity of blood of 1.056 was used to convert the units into wt/vol (15).

The calculation of Co in the Watson formula is based on estimating total body water (TBW) using the age, height and weight.

RESULTS

Figures 1 to 10 show the BAC profiles for the ten subjects as determined from the Intoxilyzer® 5000C results. Subject 1 was the only subject who appeared to be at the highest BAC by the time the first sample was taken after the end of drinking. Subjects 5 and 8 were the only ones whose BACs appeared to rise significantly after the end of drinking, with rises of 17 mg% and 22 mg%, respectively. These differences were calculated from the highest BAC and the first reading taken after the end of drinking. The remainder of the subjects showed no change or slight decreases in their BACs after the end of drinking for approximately one to two hours before their BACs followed a linear decline. Despite the prolonged periods of time where the BACs of several subjects remained relatively constant, the longest time required for any of the subjects to reach their highest BAC was 22 minutes after the end of drinking.

The Co values determined experimentally for the subjects are reported in Table 3, along with the calculated values using the Widmark and Watson formulae. Generally, the Watson formula predicted Co values more closely than did the Widmark formula, particularly for females. For males, using the Widmark formula, 17% of the subjects were within ±5% of the experimental Co values, 50% were within ±10% and 67% were within ±15%. However, using the Watson formula, these numbers improved to 50% being within ±5% of the experimental values, and 83% being within ±10%. For females, using the Widmark formula, none of the subjects were within ±10% of the experimental Co values, and 25% were within ±15%. Using the Watson formula, 25% of the subjects were within ±5%, and all were within ±10% of the measured Co values.

DISCUSSION

Ideally, the best way to determine an individual's BAC at the time of an incident is by means of a blood or breath sample taken at that time. This is neither practical nor possible in real-world impaired driving investigations. However, if there is sufficient information regarding the drinking pattern of the individual prior to and after the incident, an estimate of the individual's BAC, at the time of the incident, can be made by extrapolating back from a BAC that was determined some time after the incident.

TABLE 3

Comparison of Co Values Obtained for the Subjects (graphical Co) with the Co as calculated from the Widmark and Watson formulae

Subject	Widmark Co (mg%)	Watson Co (mg%)	Graphical Co (mg%)
		Males	
1	217	233	230
2	218	227	173
4	216	216	238
6	177	171	171
9	172	154	139
10	193	175	171
		Females	
3	268	243	218
5	251	208	189
7	247	210	193
8	224	201	195

The present study shows that there is significant variation in the BAC profiles of individuals under similar real-world drinking conditions. Only one subject was at his highest BAC when the first sample was taken after the end of drinking, however, all subjects showed that they reached their highest BAC within 22 minutes after the end of drinking. In only two subjects was there a significant rise in BAC after the first sample, following the end of drinking, was taken, with the greatest rise being 22 mg%. After the end of drinking, the BACs of most of the subjects remained relatively constant for an extended period of time, or showed a slight decline. On average, 69 minutes elapsed from the end of drinking until the start of the linear decline in BAC, with the longest time being 124 minutes. This is consistent with Winek et al (21) who reported a mean absorption time of 42.2 minutes with a range of 1 - 130 minutes and Rauschke et al (22) who found that most of their subjects were in the postabsorptive phase within 30 minutes and all within 90 minutes. This demonstrates that even in social drinking situations, absorption of alcohol can continue for up to 2 hours after the end of drinking. Although there was a prolonged absorption period after the end of drinking in many subjects, there was no significant rise in BAC. This is due to alcohol being eliminated from the body at the same rate that it is being absorbed (i.e. a plateau). Jones' study (12) which involved alcohol consumption together with a large meal showed generally longer times to peak BAC (mean 78 minutes, range 0 - 230), as well as a greater rise in BAC after the first sample (mean 17 mg%, range 0 - 45). This is not unexpected, since the subjects in his study consumed alcohol at a much faster rate than in the present study. Similar to Jones' study, all subjects in the present study had reached at least 80% of their peak BAC within 10 minutes after the end of drinking. These results are also consistent with the study by Breen et al (20).

The findings of the present study are also very similar to those of Zink and Reinhardt (10). In their study, subjects consumed alcohol over a prolonged period of time (4 to 10 hours) and achieved BACs much higher than in the present study (190 to 380 mg%). Of the 14 subjects tested, eight had attained their peak BAC at or before the end of drinking. Of the remaining 6 subjects, all had reached their peak BAC within 50 minutes after the end of drinking.

The mean elimination rate of alcohol was determined by this study to be 19 mg%/hr (range 15.4 to 21.7). This is in agreement with other published studies (16,17). Since the elimination rates were calculated using a number of points on the linear portion of the BAC curve, abnormally low values, which have been reported in the past (18, 19), were not seen. This illustrates the importance of knowing the entire BAC profile before making any conclusions with respect to a person's elimination rate.

Despite the small number of subjects in this study, the findings with respect to the Co values are strikingly similar to those reported by Watson et. al. (14). It would appear from these findings that the Watson formula is generally better able to predict Co values when compared to the Widmark formula, especially in female subjects. For women, there is a greater tendency for the Widmark formula to overestimate the Co value.

CONCLUSIONS

In a drinking experiment involving ten subjects under realistic social conditions the time to the maximum BAC was obtained on average 12 minutes (range 4 to 22 minutes) after the end of drinking. This is significantly shorter than for experiments not involving drinking under social conditions. The mean time from the end of drinking to the start of the linear decline was 69 minutes (range 0 - 124 minutes). The mean elimination rate as determined from multiple points on the linear portion of the BAC profiles was 19 mg%/hr (range 15.4 to 21.7 mg%/hr). No abnormally low elimination rates were found.

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