Blood Alcohol Levels After Drinking

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Many studies have been reported on blood alcohol levels in humans after the consumption of alcohol, normally under fasting conditions. With the development of improved instruments for measuring alcohol concentrations in the breath, it has become possible to repeatedly screen relatively large numbers of people who had been drinking under near normal social conditions.

The present investigation followed studies on twenty-eight volunteers who had consumed vodka with water under fasting conditions. Blood and breath alcohol analyses were carried out over several hours to obtain data on rates of equilibration through the body water, maximum blood alcohol levels with standard alcohol intakes and rates of elimination (factors). The results were used as a guide in preparing a chart relating the quantity of alcohol consumed to maximum blood alcohol levels of 100 mg/100 ml of blood for men and women consuming either beer or spirits. The chart was subsequently included in the report of the Royal Commission of Inquiry into the Sale of Liquor in New Zealand as an example of material which might be prepared to guide individuals who drink and drive. Calculations were based on ideal weight values related to a height and frame classification giving a close estimate to the total amount of body water. It was assumed that the drinks were consumed rapidly and the individuals had not eaten for several hours.

Some figures from the chart follow, related to beer with an alcohol concentration of 2.8% w/v and spirits at 34% w/v:

**Beer:**
- A male of height 5'8" and medium frame size:
  - 10 7 oz (or 200 ml) glasses
- A female the same height and frame size:
  - 8 7 oz (or 200 ml) glasses

**Spirits:**
- A male of height 5'6" and small frame size:
  - 8 nips (1 nip = 0.62 oz)
- A female of the same height and frame size:
  - 6 nips

The Widmark factors used in the calculations were r = 0.68 for men and 0.55 for women. These were considered to be close to the mean of experimental values reported in the literature. The quantities of beer and spirits calculated to give maximum blood alcohol levels of 100 mg/100 ml blood correspond closely to the amounts which would be expected from the volunteer studies referred to previously.

Although the quantities calculated could guide drinkers on amounts of alcohol which might give a particular maximum blood alcohol level, the conditions specified under which the alcohol was consumed were different from what would be considered as normal social drinking. For example, the consumption of 176 ml (10 nips) of spirits or 2 litres (10 200 ml glasses) of beer in 20 minutes would be abnormal drinking for most people.

It was therefore decided to test volunteers under conditions more nearly approximating normal social drinking. In two studies, the alcohol, as beer or spirits diluted with a carbonated soft drink, was consumed over a period of one hour commencing one hour after a normal evening meal.

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PROCEDURES

Study A

Six volunteers (3 male and 3 female) aged between 20 and 25 drank the quantities of alcohol calculated, as described previously on the basis of their height and frame size, to give a maximum alcohol level of 110 mg/100 ml blood, if it were consumed rapidly prior to a meal. The alcohol was taken as either beer or spirits with a diluent and consumed over a one-hour period, one hour after a normal evening meal. Blood alcohol levels were estimated from breath alcohol analyses on a Mark IV Intoximeter, commencing fifteen minutes after the drinking period. Each subject was tested sequentially, taking thirteen minutes to test all six volunteers. Testing was then repeated with the volunteers in the same order until a total of nine estimations for each volunteer had been obtained.

Study B

In Study A, a small number of volunteers were breath-tested repeatedly for about two hours after drinking had stopped. As an alternative approach it was decided to test a relatively large number of volunteers in a short period of time after it was estimated that a maximum blood alcohol level had been attained. Only one or two breath tests could be carried out on each volunteer in this type of study.

Arrangements were made for a group of forty-five young adult males and females to drink freely either beer or spirits during a one-hour period, one hour after an evening meal. Breath alcohol analyses were carried out on each volunteer commencing one hour after the drinking period using either a Mark IV Intoximeter or a Carle gas-chromatograph. A further fifteen young adults who had not been drinking subjected the individuals who had consumed alcohol to a number of tests designed to check performance and reactions in carrying out some simple tasks.

RESULTS

Study A

Summarised results from the study with six volunteers are given in Table I.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Sex</th>
<th>Alcohol</th>
<th>Volume (ml)</th>
<th>BAL max (mg/100 cm³)</th>
<th>‘r’</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH</td>
<td>M</td>
<td>Beer</td>
<td>2250</td>
<td>59</td>
<td>1.00</td>
</tr>
<tr>
<td>BA</td>
<td>M</td>
<td>Beer</td>
<td>2250</td>
<td>87</td>
<td>1.00</td>
</tr>
<tr>
<td>CD</td>
<td>M</td>
<td>Beer</td>
<td>2250</td>
<td>49</td>
<td>1.03</td>
</tr>
<tr>
<td>SF</td>
<td>F</td>
<td>Beer</td>
<td>1500</td>
<td>65</td>
<td>0.76</td>
</tr>
<tr>
<td>KS</td>
<td>F</td>
<td>Whisky</td>
<td>100</td>
<td>63</td>
<td>0.78</td>
</tr>
<tr>
<td>JC</td>
<td>F</td>
<td>Whisky</td>
<td>100</td>
<td>46</td>
<td>1.04</td>
</tr>
</tbody>
</table>

Study B

The forty-five subjects consumed a total quantity of 48.3 litres of beer and 4.35 litres of spirits and individual consumptions ranged from 6 to 200 grams of absolute alcohol. Twenty-three drank beer only and twenty-two spirits only. The estimated blood alcohol levels for
the group ranged from 1–120 mg/100 ml and there was a significant correlation between
the amount of alcohol ingested and the blood alcohol level. This correlation improved when
doses in grams per kilogram body weight were plotted against blood alcohol levels (Figure
1), and statistical analysis gave a regression coefficient of 79 (confidence interval 70 –
87) with a correlation coefficient of 0.978. The mean time for the breath test was ninety
minutes after drinking had stopped. Regression analysis of time versus blood alcohol level
showed an average decline of 10 mg/100 ml from those tests taken at the beginning of the
period to those taken at the end. This decline was small but affected the analysis slightly
be decreasing the correlation coefficient.

![Figure 1](image)

**Correlation between alcohol consumed (g/kg body weight) and blood alcohol
levels (mg/100 ml blood).**

The source of alcohol, whether beer or the various spirits that were available, had no
effect on the resulting blood alcohol levels which were only related to the amount of absolute
alcohol consumed. (Table II.)

<table>
<thead>
<tr>
<th>TABLE II</th>
<th>Mean dose and blood alcohol level for beer and spirit drinkers.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BAL mean mg/100 cm³</td>
</tr>
<tr>
<td>Beer</td>
<td>54</td>
</tr>
<tr>
<td>Spirits</td>
<td>53</td>
</tr>
</tbody>
</table>

It is of interest to note that the consumption calculated as absolute alcohol by each
group was identical averaging 63 grams per person. The number of females in the study
were few and their alcohol consumption low, but their blood alcohol levels in the lower
range were indistinguishable from those of the males when calculated on a dose per kilogram
basis.
DISCUSSION

The quantity of alcohol required to give a maximum blood alcohol level, after equilibration, of 100 mg/100 ml blood may be almost doubled if consumed during an hour after a meal compared with calculated quantities for rapid drinking prior to a meal.

In the first study, nine breath analyses were carried out on each volunteer and reasonably accurate Widmark factors and maximum blood alcohol levels could be determined. With the second study, a large number of people were breath-tested once or twice after drinking with the surprising finding that there was a very high correlation for the group between grams of ethanol consumed/kg body weight and the blood alcohol level. From the regression coefficient an equation could be derived which gives a likely blood alcohol level from grams of alcohol consumed/kg body weight. The expression for this study follows:

\[ g \text{ ethanol consumed/kg body weight} \times 79 - 12 \]

where 79 is the blood alcohol level attained at an ingestion level of 1 g ethanol/kg body weight and 12 is the negative intercept on the ordinate.

It is clear that a different Widmark ratio is required when calculating blood alcohol levels for individuals consuming alcohol after a meal.

An alternative expression to the Widmark equation uses the following ratio published by Harger and Forney in 1963

\[ \text{Factor} = \frac{\text{peak blood alcohol} \times \text{body weight (kg)}}{\text{alcohol dose (g)}} \]

This ratio permits comparisons to be made of results from authors who have published data only on peak blood alcohol levels rather than from the complete elimination curves required to derive the Widmark ratio. An advantage of the Harger and Forney expression is that the peak blood alcohol level may be calculated rapidly if the alcohol dose in grams per kilogram body weight is known. As an example, a dose of 0.5 g alcohol/kg body weight and a factor of 124 would correspond to a peak blood alcohol level of 62 mg/100 ml blood. Values from the literature and from our studies are given in Table III.

A number of factors affect the rates of absorption of alcohol into the body. Some which are frequently quoted follow:

Alcohol absorption rate

(1) Decreased by – (a) food in stomach  
(b) factors in beer (e.g. carbohydrate)  
(c) high alcohol concentrations  
or (d) vasoconstriction (adrenaline — stress)

(2) Increased by – (a) carbonation (e.g. from tonic water added to gin)  
(b) prior drinking

With an empty stomach and rapid consumption of small quantities of alcohol, there is a rapid movement of the alcohol into the small intestine and, consequently, rapid absorption. When there is food in the stomach, the alcohol mixes with the stomach contents and movement into the small intestine is retarded while digestion proceeds.

Haggard, Greenberg and Lolli showed that alcohol absorption, after an initial rapid rate, depended on gastric emptying. Large quantities or high concentrations of alcohol may cause spasms of the pyloric sphincter which controls the rate of passage of stomach contents into the small intestine. It is possible that the very variable alcohol absorption patterns observed in individuals consuming alcohol in a fasting condition are due to individual differences in the effect alcohol is having on the pyloric sphincter. With Study B, where all the members of the group had had a similar meal and consumed alcohol under basically the same conditions, the controls on stomach emptying might be expected to be much less variable than with fasting individuals.
TABLE III  Maximum blood alcohol levels.

<table>
<thead>
<tr>
<th>Author</th>
<th>Date</th>
<th>Factor*</th>
<th>Alcohol</th>
<th>Drinking Time (Minutes)</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haggard et al.</td>
<td>1938</td>
<td>158 ± 40</td>
<td>Spirits</td>
<td>Rapid - Chemical</td>
<td>Fasting Spirits</td>
</tr>
<tr>
<td>Bayly and</td>
<td>1958</td>
<td>105</td>
<td>Fed</td>
<td>Rapid - Breathalyser</td>
<td>Spirits</td>
</tr>
<tr>
<td>McCallum</td>
<td></td>
<td>118</td>
<td>Fed</td>
<td>Rapid - Breathalyser</td>
<td>Spirits</td>
</tr>
<tr>
<td>Coldwell et al.</td>
<td>1958</td>
<td>97 ± 40</td>
<td>Fed</td>
<td>60 - Breathalyser and Blood</td>
<td>Spirits</td>
</tr>
<tr>
<td>Couchman</td>
<td>1974</td>
<td>124 ± 40</td>
<td>Fasting</td>
<td>10 - Blood</td>
<td>Spirits</td>
</tr>
<tr>
<td>Mortimer and</td>
<td>1974</td>
<td>120</td>
<td>Fed</td>
<td>60 - Blood</td>
<td>Spirits</td>
</tr>
<tr>
<td>Sturgis</td>
<td></td>
<td>69 (light drinkers)</td>
<td>Fed</td>
<td>180 - Blood</td>
<td>Spirits</td>
</tr>
<tr>
<td>Kalant et al.</td>
<td>1974</td>
<td>88 (heavy drinkers)</td>
<td>Fed</td>
<td>120 - Breathalyser</td>
<td>Spirits</td>
</tr>
<tr>
<td>Santamaria</td>
<td>1974</td>
<td>75</td>
<td>Fasting</td>
<td>120 - Breathalyser</td>
<td>Spirits</td>
</tr>
<tr>
<td>Couchman</td>
<td>1975</td>
<td>70</td>
<td>Fed</td>
<td>60 - Intoximeter</td>
<td>Spirits</td>
</tr>
</tbody>
</table>

*Factor = \[
\frac{\text{Peak Blood Alcohol Level}}{\text{Dose in grams-kg}}
\]
The factor equals the maximum blood level in mg/100 ml if the dose is equal to 1 g/kg body weight.

![Figure 2](attachment:figure2.png)

Changes in blood alcohol levels and isotope abundance after ingesting deuterated ethanol.

From preliminary studies using alcohol labelled with deuterium, changes in rates of equilibration may be interpreted as due to changes in controls on the pyloric sphincter. In a preliminary experiment, a volunteer who had eaten lunch about an hour earlier, was given
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deuterium labelled ethanol twenty minutes after a main dose of unlabelled ethanol. Figure 2 shows the rapid rate of equilibration of about 80% of the deuterium labelled ethanol with the alcohol which had already diffused through the body water. The oscillating pattern of absorption seen in the early stages of total alcohol absorption (upper graph) is reflected in the oscillating isotope abundance ratios for the deuterium labelled ethanol as estimated in breath samples. The very slow rate at which the last 15-20% of the deuterium labelled ethanol fully equilibrates with the unlabelled ethanol, i.e. in about two hours, could be due to the pyloric sphincter retaining some of the alcohol in the stomach after an initial high emptying rate. The oscillations observed in breath alcohol concentrations for both the total and deuterium labelled ethanol may directly reflect openings of the pyloric sphincter with a subsequent very rapid alcohol absorption from the small intestine. Further studies are being undertaken to examine these equilibration findings in more detail.

The results from this and other investigations show that drinking with or after a meal reduces by approximately 50% the maximum blood alcohol level attained. It would also seem that rates of alcohol absorption may be more uniform, from person to person, if the alcohol is consumed after a meal in comparison with a fasting state.

REFERENCES