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The Effect of Food on Alcohol Absorption and Elimination Patterns

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ABSTRACT: The same nine subjects (six male, three female) were given near bolus doses of alcohol (0.69 g/kg) on two occasions separated by one week. They were instructed to consume the alcohol as rapidly as possible (12.1 min average). The alcohol was consumed after dilution to 15% with fruit punch mix. Both phases of the experiment were conducted in a similar manner with the exception of stomach condition. In Phase I the alcohol was consumed immediately after a large meal. In Phase II, the alcohol was consumed after an approximate 6 h fast. An Intoxilyzer 4011A was used to measure Breath Alcohol Concentration (BrAC), beginning immediately after the alcohol was consumed and ending approximately 4 h after the end of drinking. The BrACs were measured in grams per 210 L of breath, at approximate 8 min intervals over the course of the experiment. The alcohol absorption and elimination curves were plotted and evaluated for each subject in both experiments. The average time required to reach maximum BrAC was 41 min for both empty and full stomach conditions. The average elimination rate of ethanol was found to be significantly lower after a meal (0.017 BrAC/h compared to 0.020 BrAC/h) but the time required to reach zero BrAC was not significantly different (5.01 h full stomach, 5.05 h empty stomach).

KEYWORDS: toxicology, breath alcohol, ethanol, alcohol concentration, alcohol absorption, alcohol elimination, time to maximum, maximum reached, driving under the influence

Alcohol absorption and elimination patterns are frequently key elements in the medico-legal evaluation of driving under the influence (DUIs) and alcohol involved accidents. Criminalists are frequently called upon to estimate alcohol concentrations at the time of driving or accident. These estimates are generally based upon a breath test taken at a later time. This operation is known as retrograde extrapolation (also back calculation, or relation back).

At least two state courts have decided that breath test results are inadmissible unless there is evidence relating the measured result to the time of driving [*1,2*]. Consequently, alcohol absorption and elimination patterns have become vital elements in DUI litigation.

The literature makes a number of references to the variability of alcohol absorption and elimination [*3–5*], however there are few quantitative studies of absorption and elimination patterns under different stomach conditions (empty or full stomach). Sedman et al. [*6*] evaluated the effect of various types of liquid food upon alcohol absorption and metabolism. Under those experimental conditions they found the presence of food in the

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stomach prolongs the absorption of alcohol and delays the time of occurrence of peak blood alcohol concentration.

The present experiment was designed to compare the effect of empty and full stomach conditions on the following factors:

1. Time required to reach maximum breath alcohol concentration (BrAC) after a bolus dose of alcohol.
2. Maximum BrAC attained.
3. Alcohol elimination rate from breath.
4. Time required to reach zero BrAC.
5. Theoretical maximum BrAC (C_0) [7].

Methods

Subjects and Conditions

The experiment was conducted in two phases scheduled one week apart using the same nine volunteers (six male, three female). The phases consisted of:

I Consumption of alcohol after a meal consisting of pepperoni and sausage pizza.
II Consumption of alcohol under fasting conditions.

Except for the food variable, similar conditions were maintained in both phases. The volunteers were social drinkers with no history of alcohol abuse and were instructed not to eat after noon on the day of the experiment. The experimental trials were then conducted at approximately 6:30 p.m. after approximately 6 h of fasting. The volunteers were weighed and dosed at 0.69 g/kg. The alcohol solutions were 15% v/v (in fruit punch mix) and were consumed as rapidly as possible (Avg. 12.1 min, range 25 min). In phase I all subjects consumed the same kind of pizza immediately prior to the ingestion of the alcohol solution.

Breath Testing and Equipment Used

Breath testing began after the consumption of the alcohol solutions. Immediately after the consumption of the solution each subject was instructed to rinse the mouth with tap water. The BrACs were then measured at approximate 8 min intervals over a period of approximately 4 h.

An Intoxilyzer model 4011A was used for all BrAC measurements. The analytical capabilities of this instrumentation have been evaluated by Emerson et al. [8]. Prior to testing, the Intoxilyzer calibration was checked at the 0.10 BrAC level using a wet bath Simulator. All BrACs are reported as grams of alcohol per 210 L of breath.

Results

The breath alcohol concentrations were plotted against time (Figs. 1 and 2), and from these plots the time to maximum BrAC, the maximum BrAC attained, the alcohol elimination rate, the time required to reach zero BrAC, and theoretical maximum BrAC (C_0) were noted. These values, their averages and standard deviations appear in Table 1. Time zero for each plot was considered to be the midpoint of the drinking time for each volunteer.

The time required to reach maximum BrAC was considered to be the time at which the BrAC reached within 0.003 BrAC of the highest value attained. This averaged 41

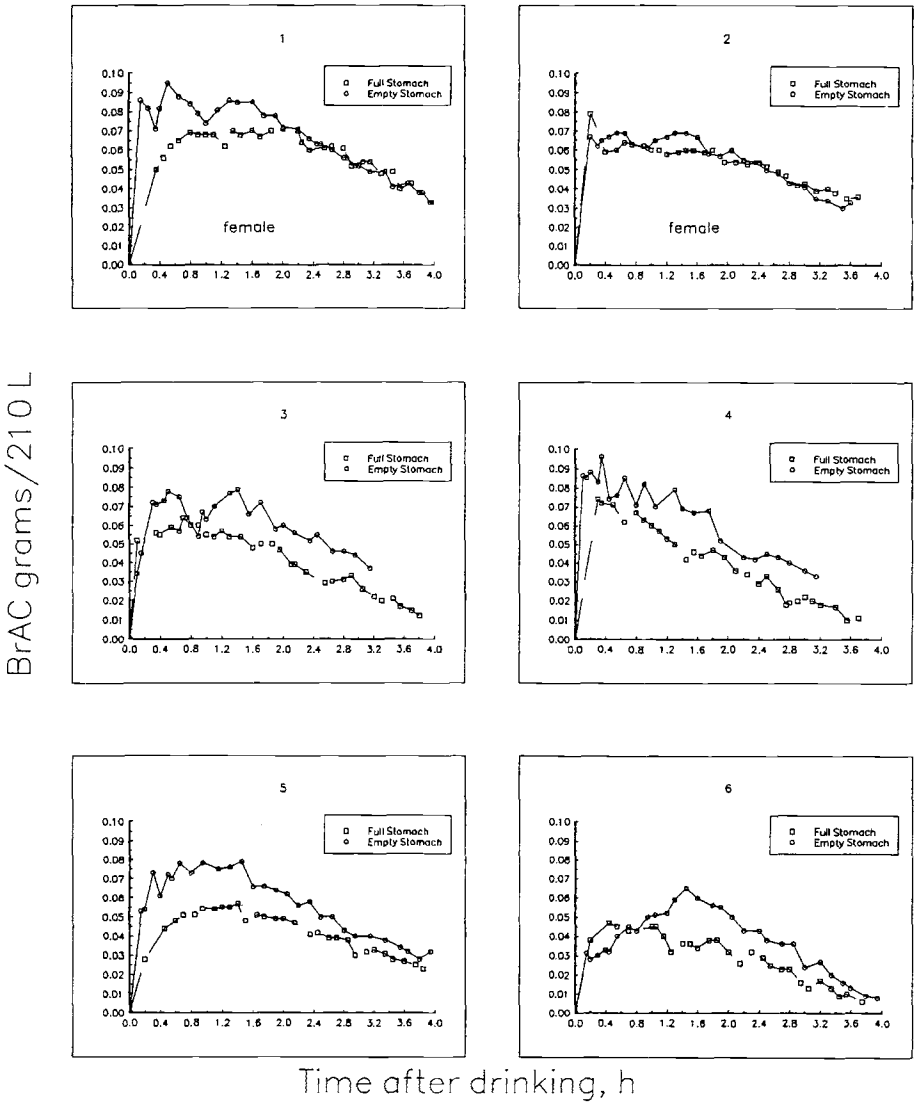

FIG. 1—*Breath ethanol concentration-time plots for six different subjects after they drank 0.69 g of ethanol per kg of body weight as 15% ethanol/punch mix. The subjects consumed the ethanol as rapidly as possible on an empty stomach and after a large meal.*

min for both full and empty stomach conditions, with a range of 43.8 for the full condition and 75 min for the empty condition.

The theoretical maximum (C_0) for each individual was determined by projecting the negatively sloped, relatively linear portion of the curve (after approximately 1.5 h absorption time) backward to time zero. The alcohol elimination rates were determined by dividing the Y intercepts of these lines by the X intercepts yielding the change in BrAC per unit time.

The average time required to return to zero BrAC was similar in both conditions (Full—5.01 h, empty—5.05 h).

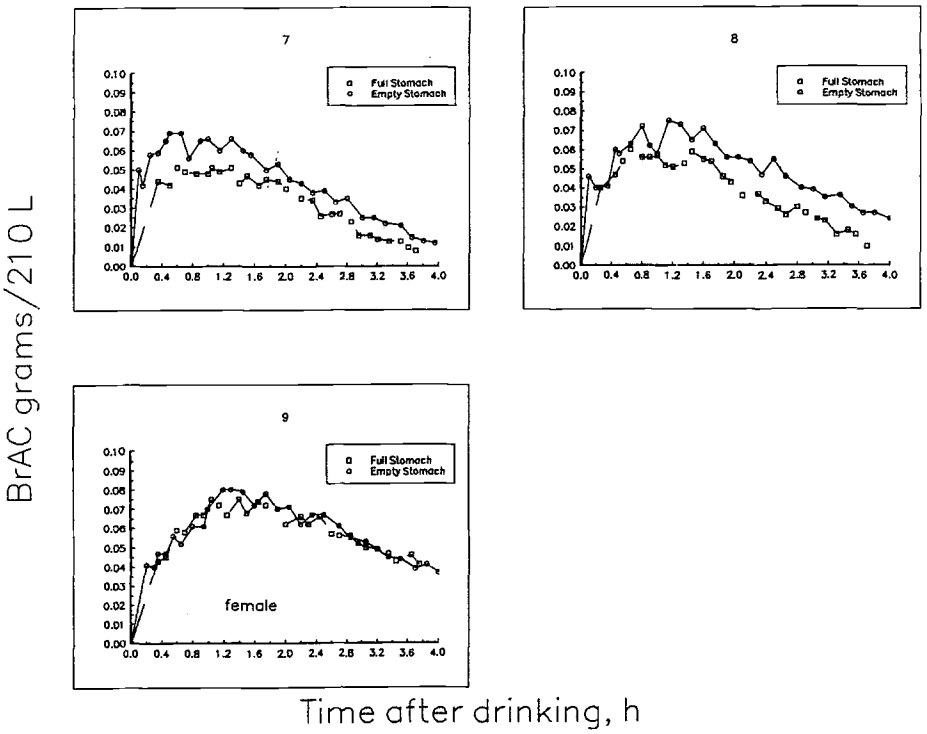

FIG. 2—*Breath ethanol concentration-time plots for three different subjects after they drank 0.69 g of ethanol per kg of body weight as 15% ethanol/punch mix. The subjects consumed the ethanol as rapidly as possible on an empty stomach and after a large meal.*

Discussion

As expected, the presence of food in the stomach reduced the peak BrACs (averaging 21.5% lower). However, regardless of stomach condition the time required to reach maximum BrAC was relatively short, on average being 41 min. The most important finding of this study was the short time required to reach the maximum BrACs, and the failure of food to prolong the rising phase (upward sloped leg of the BrAC curve).

It appears that a large portion of alcohol ingested is rapidly absorbed directly through the stomach. In a review article, [*9*] Holt noted that up to 43% of an administered dose of alcohol may rapidly diffuse through the stomach wall within the first 20 min after ingestion. Cortot et al. [*10*] found 73% of the alcohol ingested was absorbed from the stomach. They found 39.4% of the ingested alcohol was absorbed through the stomach within the first hour after a meal. McFarlane et al. [*11*] found that infusion of lipids into the ileum and duodenum significantly delayed gastric emptying and depressed the maximum blood alcohol concentrations (BACs) reached. However, even under these conditions, maximum BAC was reached within 0.5 h, while 100% of the nonabsorbable radioactive marker remained in the stomach.

We found that the alcohol elimination rate was lower in the full stomach condition compared with the empty stomach condition (0.017 BrAC/h vs. 0.020 BrAC/h). The difference was statistically significant according to the paired-sample t-test. However the time required to eliminate all of the alcohol in the system was not significantly different.

TABLE 1—*BrAC (g/210L) results after near bolus dose of alcohol (0.69 g/kg).*

Subject #/age/wt/sex kg	Time to Max BrAC, h From mid pt of drinking	From end of drinking	Max BrAC	Theoretical Max BrAC, C_0	Time to 0 BrAC, h	Elimination Rate, BrAC/h
			Empty stomach			
1/39/79.3/f	0.48	0.36	0.095	0.116	5.55	0.021
2/27/65.5/f	0.20	0.14	0.068	0.097	5.05	0.019
3/29/89.1/m	0.53	0.51	0.079	0.106	4.90	0.022
4/32/96.3/m	0.35	0.29	0.096	0.095	4.80	0.020
5/23/78.2/m	0.65	0.64	0.080	0.100	5.35	0.019
6/36/87.2/m	1.45	1.39	0.065	0.098	4.20	0.023
7/25/68.2/m	0.53	0.46	0.069	0.088	4.45	0.020
8/43/101/m	0.83	0.75	0.075	0.097	5.05	0.019
9/41/64.6/f	1.20	1.11	0.080	0.105	6.15	0.017
Mean	0.689	0.628	0.079	0.100	5.056	0.0200
SD			0.010	0.008	0.549	0.0017
Range	1.25	1.25				
			Full stomach			
1	0.80	0.58	0.069	0.106	6.20	0.017
2	0.67	0.52	0.062	0.083	6.10	0.014
3	0.73	0.64	0.064	0.082	4.45	0.018
4	0.32	0.19	0.074	0.080	4.10	0.020
5	0.93	0.84	0.054	0.077	5.40	0.014
6	0.46	0.36	0.047	0.066	4.20	0.016
7	0.58	0.43	0.051	0.078	4.10	0.019
8	0.65	0.48	0.060	0.086	4.20	0.020
9	1.05	0.89	0.075	0.100	6.35	0.016
Mean	0.687	0.548	0.062	0.084	5.011[a]	0.0171[b]
SD			0.009	0.011	0.933	0.0023
Range	0.73	0.70				

[a]No significant difference from empty stomach. $t = 0.2146$ $P = 0.83$.
[b]Significantly different from empty stomach. $t = 3.194$ $P < 0.05$.

These observations may be explained by two different mechanisms. One possibility is that the rate of alcohol metabolism is actually slower in the full stomach condition but the first pass metabolism in the stomach reduced the amount of alcohol by just the right amount to require precisely the same amount of time to reach zero BrAC. The other possibility is that the metabolic rate remained the same in the full stomach condition and that the alcohol absorption continued at a relatively low linear rate from the time of peak alcohol concentration until reaching zero BrAC. The most likely explanation would appear to be the latter because it does not require the precisely balanced action of two unrelated mechanisms.

All of the elimination rates measured in this study were within the range commonly used by forensic scientists in connection with retrograde extrapolations [*12–14*].

The rapid fluctuations of BrAC with time noted by Dubowski [*3*] were seen in this study during the empty stomach condition. They appeared primarily within the first 1.5 h after drinking and were generally absent afterwards. The maximum fluctuations were around 0.02 BrAC in magnitude and were short-lived, lasting 0.5 h or less. We would speculate that they reflect the opening and closing of the pyloric valve, thus dumping alcohol into the intestine in a series of waves.

All five of the factors studied appear to be reasonably predictable and sufficiently reliable to make estimates of BrACs at some time removed from the time of a breath test. However useful such estimates may be in DUI cases, it should be remembered that the process of alcohol absorption is highly variable. The limitations and pitfalls associated with retrograde extrapolations are often not appreciated by laymen and the courts. Any attempt at retrograde extrapolation should be made with caution, and performed by persons able to assess and discuss the applicability of a retrograde estimate to a particular situation.

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References

[*1*] Desmond V. Superior Court, 161 Ariz. 522, 779 P.2d 1261, 1989.
[*2*] State v. Dumont. 146 Vt. 252, 499 A.2d 787, 1985.
[*3*] Dubowski, K. M., "Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects," *Journal of Studies on Alcohol*, Suppl. No. 10, 1985, pp. 98–108.
[*4*] Martin, N. G., Perl, J., Oakeshott, J. G., Gibson, J. B., Starmer, G. A., and Wilks, A. V., "A Twin Study of Ethanol Metabolism," *Behavior Genetics*, Vol. 15, 1985, pp. 93–109.
[*5*] Camps, F. E., Ed., *Gradwohl's Legal Medicine*, Third Edition, Chicago, A. John Wright and Sons, 1976, p. 567.
[*6*] Sedman, A. J., Wilkinson, P. K., Sakmar, E., Weidler, D. J., and Wagner, J. G., "Food Effects on Absorption and Metabolism of Alcohol," *Journal of Studies on Alcohol*, Vol. 37, 1976, pp. 1197–1214.
[*7*] Widmark, E. M. P., *Principles and Applications of Medicolegal Alcohol Determination*, Biomedical Publications, Davis, CA., 1981, p. 48.
[*8*] Emerson, V. J., Holleyhead, R., Isaacs, M. D. J., Fuller, N. A., and Hunt, D. J., "The Measurement of Breath Alcohol," *Journal of Forensic Science Society*, Vol. 20, 1980, pp. 3–70.
[*9*] Holt, S., "Observations on the Relation Between Alcohol Absorption and the Rate of Gastric Emptying," *Canadian Medical Association Journal*, Vol. 124, 1981, pp. 267–277.
[*10*] Cortot, A., Jobin, G., Ducrot, F., Aymes, C., Giraudeaux, V., and Modigliani, R., "Gastric Emptying and Gastrointestinal Absorption of Alcohol Ingested with a Meal," *Digestive Diseases and Sciences*, Vol. 31, 1986, pp. 343–348.

[*11*] McFarlane, A., Pooley, L., Welch, I. M., Rumsey, R. D., and Read, N. W., "How Does Dietary Lipid Lower Blood Alcohol Concentrations?" *Gut*, Vol. 27, 1986, pp. 15–18.
[*12*] Shajani, N. K. and Dinn, H. M., "Blood Alcohol Concentrations Reached in Human Subjects After Consumption of Alcoholic Beverages in a Social Setting," *Canadian Society of Forensic Science Journal*, Vol. 18, No. 1, 1985.
[*13*] Kirk, P. L., *Crime Investigation*, (2nd edition), J. I. Thornton, Ed., John Wiley & Sons, Inc., 1974, p. 349.
[*14*] Saferstein, R., *Forensic Science Handbook*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1982, p. 597.

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