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Alcohol breath tests: Criterion times for avoiding contamination by "mouth alcohol"

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Using either a gas chromatography or an infrared absorption technique, series of blood alcohol concentrations (BACs) determined by breath tests were obtained from human subjects immediately subsequent to their having only oral contact with beverages ranging in ethyl alcohol concentration from 4% to 95%+. Times for total dissipation of mouth alcohol residuals to a level of practical nonsignificance ranged from 10 to 19 min. Dissipation rates were an inverse and approximately exponential function of the ethyl alcohol concentration of the beverage and were greatly shortened by rinsing the mouth with warm (34°C) water prior to testing. The results are discussed in terms of their relevance to the methodology of a number of research studies employing BAC breath-testing equipment.

The indirect measurement of blood alcohol concentration (BAC) from alveolar gas analysis[1] (breath testing) has become the most widely used, accurate, and simple method of estimating the degree of an individual's intoxication. Numerous studies using a variety of breath-analyzing instruments attest to the utility of the method and the accuracy of the instruments (see, for example, Coldwell, Solomonraj, Trenholm, & Wilberg, 1971; Erwin, Greenberg, & Minzer, 1972; Lovell, 1972). Interestingly, however, studies investigating the influence of mouth alcohol (alcohol dissolved in the mucous membranes that interface the gas and/or fluid passages of the mouth and pharyngeal cavities) on alveolar gas analysis have not yielded entirely consistent results.

Borkenstein (1963), in the operating manual of the Breathalyzer,[2] failed to specify the duration of the influence of mouth alcohol on alveolar gas analysis. Subsequently, however, Borkenstein (Note 1) indicated that law enforcement agencies are particularly aware of the necessity of a waiting period, which, typically, they set at not less than 20 min and often 30 min. [See also American Medical Association, 1968; Borkenstein & Smith, 1961; Pruit vs. State of Tennessee (393 SW 2nd, 747, 1965; cited in American Medical Association, 1968); Smith & Lucas, 1958; State of Washington vs. Baker, Note 2.]

Elbel and Schleyer (1956), on the other hand, claimed (without reporting experimental evidence) that minor errors may occur for up to 1 h after alcohol ingestion, and that breath analysis conducted less than 15 min after ingestion of alcoholic beverages leads to considerable, although unspecified, errors. Spector (1971) reached a similar conclusion.

While, for legal purposes, it is necessary to establish a very conservative criterion waiting period beyond which there is no chance that any mouth alcohol will influence BAC determination, the 20- and 25-min standard waiting time used in criminal justice procedures has proved to be inconvenient, and may prove unnecessary, when it is applied as a methodological requirement of some alcohol research studies. For example, recent studies examining the effects of doses of alcohol shortly after administration (Briddell & Wilson, 1976; Huber, Karlin, & Nathan, 1976; Flynn & Caddy, Note 3; Vuchinich & Sobell, Note 4; and others) typically have abided by the 20- to 25-min waiting period. Yet these studies have all used relatively low-alcohol-concentration beverages, which one investigator (Dubowski, 1975) has indicated may result in the complete dissipation of mouth alcohol within a period of 11 min after ingestion or expectoration.

It is also not clear whether the technique of rinsing the mouth with water following the consumption or expectoration of an alcoholic beverage significantly changes the rate of dissipation of mouth alcohol. Spector (1971) explored the possible effect of various procedures, including rinsing the mouth with water, on the rate of dissipation of mouth alcohol and found that these procedures did not significantly influence the rate of this process. But Spector used cold tap water (temperature unspecified), which may have produced a lowering of the breath-sample temperature which, in turn, may have led to spurious instrument readings.

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Dubowski (1975) provided evidence contradicting Spector's findings. As a component of his study, Dubowski required eight subjects to undertake two 20-sec rinsing tasks (using distilled water at room temperature), following the expectoration of an alcoholic (11.4% volume/volume) beverage. This procedure resulted in all eight subjects' being completely free of mouth alcohol within 8 min of their having expectorated the beverage.

Finally, there are no data currently available that address the extent to which possible shortened criterion clear-out intervals are stable when different instruments and different analytic techniques are employed to monitor very low BACs.

This paper reports on experiments that addressed the following questions: (1) In what manner does mouth alcohol influence alveolar gas analysis when BAC is assessed using gas chromatographic or infrared spectrophotometric instruments? (2) To what extent are the criterion intervals for attaining practical nonsignificance of mouth alcohol a function of the ethanol concentration of the beverage consumed? (3) Do interindividual and intraindividual differences exist in the rate of mouth alcohol dissipation? (4) Is it possible to accelerate the rate at which mouth alcohol is dissipated?

EXPERIMENT 1

Method

Experiment 1 examined the influence of mouth alcohol on alveolar gas analysis when the BAC was assessed using two instruments, the Alco-Analyzer and the Intoxilyzer. The experiment also explored the extent to which beverage alcohol concentration influences the dissipation of mouth alcohol residuals.

Subjects. Twelve subjects (six males and six females), all moderate users of alcohol between the ages of 22 and 30 years, participated in this experiment.

Apparatus. Two analyzing instruments were used to determine BACs: (1) The Intoxilyzer[3] measures the absorption of infrared energy by a gas following the Lambert-Beer law of absorption. The infrared wavelength used in the Intoxilyzer coincides with a major absorption band of ethyl alcohol. In a sample cell, an increasing concentration of alcohol vapor decreases the amount of infrared energy reaching a detector in a predictable, exponential manner. The detected signal is electronically filtered and displayed on a digital readout meter. (2) The Alco-Analyzer (Model 1000)[4] provides gas chromatographic analysis of breath, blood, or urine specimens. The alveolar breath sample (or vaporized blood/urine specimen) is introduced at the beginning of a column through which a continual stream of helium is passed. The helium sweeps the material through the column so that different substances in the sample arrive at a thermal-conductivity detector at different times. The degree of thermal conductivity is then translated to an electrical signal registered on a strip-chart recorder. Both instruments are currently in use and have been shown to be highly sensitive and accurate (Harte, 1971; Luckey, 1971). During the present experiments, the accuracy of the Intoxilyzer was determined using a Mark II simulator.[5] The accuracy of the Alco-Analyzer was assessed using a Model LS-18 simulator.[6] Both simulators contained a standard alcohol solution set to mimic a BAC of .10% (mg/100 ml). Both instruments operated accurately throughout all three experiments.

Procedure. Six subjects (three males and three females) were assigned to each of the two breath-analyzing instruments. Each subject participated in 5 or 10 testing sessions (depending on the intrument assignments), with sessions separated by a minimum time interval of 2 h. Within the 30-min period preceding each session, subjects were required to refrain from smoking and to provide a breath sample to insure that all initial BAC readings were .00%.[7]

A test began with the subject's taking .5 oz of one of the five alcoholic beverages into his/her mouth, swishing the beverage throughout the oral cavity for 15 sec, and then expectorating. Beer (4% alcohol), wine (12%), bourbon (43%), vodka (45%), and ethyl alcohol (95%+) were used. Subjects were instructed not to swallow any of the beverage. Then, 15 sec after expectorating, the first breath sample was taken. In the case of the gas chromatographic analyses, apparatus limitations required that breath analyses be separated by 180 sec. For infrared analyses, the interval was 90 sec. Thus, using the Intoxilyzer, samples were obtained at 15, 105, 195, 285, 375 sec, and so on. For Alco-Analyzer subjects, the tests were divided into two groups of five tests each. The first group of tests involved a sampling interval of 180 sec. (i.e., tests were taken at 15, 195, 375 sec, and so on). The second group of tests differed from the first only in that, after expectorating, each subject waited 105 sec before providing the first breath sample. Subsequent breath samples were taken at 180-sec intervals (i.e., tests were taken at 105, 285, 465 sec, and so on). Hence, temporally synchronized data points were obtained for both Alco-Analyzer and Intoxilyzer subjects. These procedures were continued on each test until two consecutive readings of .00% were obtained. Standardization of each instrument was performed prior to each new test. To determine the test-retest reliability of the rate of dissipation of mouth alcohol, two subjects (one male and one female) were selected from each of the two apparatus conditions and required to repeat the test sequence involving the 15-sec delay.

Results

A 2 by 2 by 4 repeated-measures analysis of variance was performed using time (seconds) from expectoration to clear-out ("zero set" on Intoxilyzer, .00% on Alco-Analyzer) as the dependent variable.

A significant main effect for beverage type was found [$F(3,30) = 44.97$, $p < .001$], with the time necessary for clear-out being inversely (and possibly exponentially) related to the beverage alcohol concentration. Collapsing the data for the 105-sec and 15-sec delay conditions provided the following mean times to achieve clear-out: beer, 532.5 sec; wine, 645.0 sec; vodka or bourbon, 821.3 sec; and ethyl alcohol, 847.1 sec. The means and ranges of the BAC readings on the two instruments as a function of time since expectoration for four beverage strengths is presented in Figure 1.

The data analysis also yielded a significant interaction between type of beverage and apparatus [$F(3,30) = 7.15$, $p < .001$]. This interaction appeared to result from the Intoxilyzer being less affected by differences in beverage alcohol concentration than was the Alco-Analyzer. Such a finding is not unexpected, for the sample chamber of the Intoxilyzer requires a substantially greater breath sample for analysis than does the Alco-Analyzer. The greater expiration required by the Intoxilyzer may have led to a reduction in early breath alcohol concentrations as measured by the Intoxilyzer.

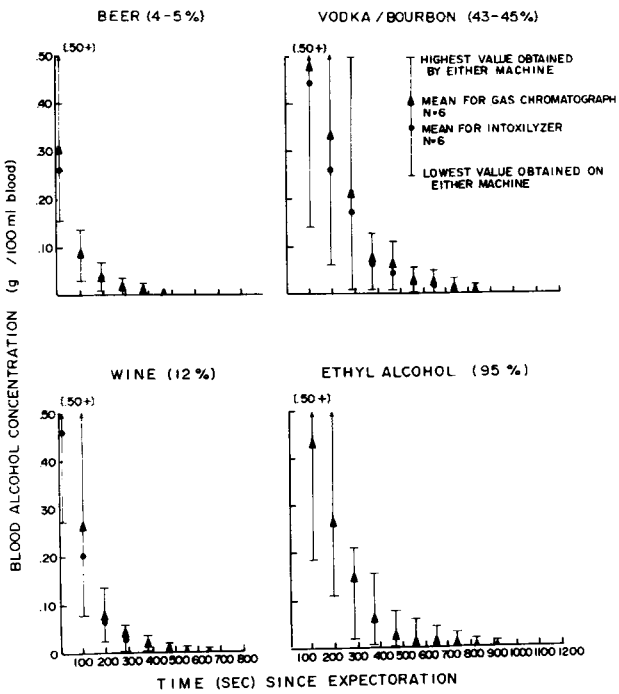

Figure 1. Means and combined ranges of blood alcohol concentration readings (g/100 ml blood), estimated by breath tests conducted on gas chromatography and infrared spectrophotometry (Intoxilyzer) devices, as a function of time (in seconds) since expectoration of four different beverage ethanol concentrations.

Test-retest reliabilities for the Alco-Analyzer subjects were calculated to be +.76 and +.95. The correlations for the two Intoxilyzer subjects were +.90 and +.96. It is noteworthy that, while the value of the actual readings differed somewhat from the first to the second test for each subject, these differences had a negligible effect on the criterion time to clear-out intervals for each of the various beverages employed.

EXPERIMENT 2

Experiment 2 sought to determine whether it is possible to accelerate the rate at which mouth alcohol may be dissipated by rinsing the mouth with water.

Method

Subjects. Eight of the subjects from Experiment 1 (four males, four females) participated in this study.

Apparatus. The breath-testing instruments were those described in Experiment 1.

Procedure. In this experiment, data were obtained on the six subjects (three males, three females) allocated to the Intoxilyzer; circumstances made it impossible to obtain data from all but two subjects (one male, one female) of the Alco-Analyzer cohort.

Subjects were required to retain in their mouths either beer or bourbon on two separate occasions, using the basic procedure of Experiment 1. Immediately after expectorating the beverage, each subject rinsed his/her mouth with lukewarm distilled water (approximately breath temperature, 34°C). After rinsing the mouth for 10 sec, the water was expectorated and additional rinsing trials were conducted continuously during the waiting intervals between breath sampling until the BACs had fallen below the Intoxilyzer "zero-set" range or reached absolute zero on the Alco-Analyzer.

Results

The effects of repeatedly rinsing the mouth with warm water on the rate of dissipation of mouth alcohol are illustrated in Figure 2. Comparing Figures 1 and 2, it is clear that the rinsing procedure markedly increased the rate of dissipation of mouth alcohol. While the criterion time interval for dissipation of beer was set at 555 sec (see Discussion), the rinsing procedure resulted in a negligible BAC reading by 285 sec after beverage expectoration. Perhaps more importantly, rinsing following the expectoration of beer produced BACs below .01% within 105 sec in all cases. Following the expectoration of bourbon, the rinsing procedure shortened the criterion time interval from 915 sec to 465 sec, with BACs below .01% occurring within 285 sec in all cases.

DISCUSSION

The results of Experiment 1 demonstrate the inverse and possibly exponential nature of the relationship between beverage alcohol concentration and the rate of dissipation of mouth alcohol. This relationship suggests that the use of different criterion clear-out intervals may be appropriate when different beverage alcohol concentrations are used in research studies. For practical purposes, however, it is not sufficient to know simply that the clear-out time for mouth alcohol varies as a function of the ethanol concentration of a beverage. Rather, it is necessary to determine the time interval following expectoration of each beverage beyond which mouth alcohol residuals can be expected to have a negligible effect on breath-derived estimates of BAC. A

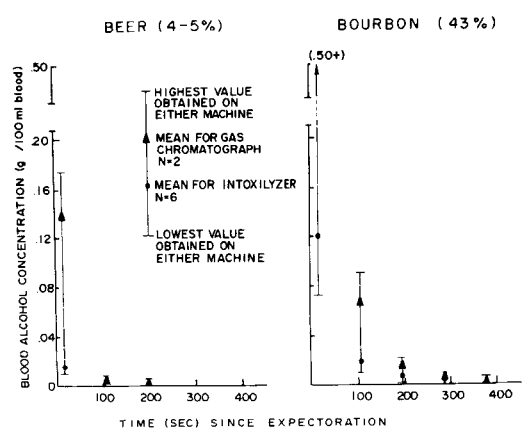

Figure 2. Means and combined ranges of blood alcohol concentration readings (g/100 ml blood), estimated by breath tests conducted on gas chromatography and infrared spectrophotometry (Intoxilyzer) devices, as a function of time (in seconds) since expectoration of beer and bourbon. Subjects rinsed their mouths continuously with 34°C distilled water between consecutive breath tests.

conservative estimate of this interval is provided by using the highest single score obtained on either machine at each time since expectoration, rather than using a score based on measures of central tendency. Employing this criterion, critical intervals beyond which mouth alcohol would no longer contaminate BAC readings were found to be: beer, t = 555 sec; wine, t = 735 sec, vodka or bourbon, t = 915 sec; and ethyl alcohol, t = 1,095 sec.

Experiment 1 also indicated a low level of intra-subject differences as far as rate of dissipation of residual mouth alcohol is concerned, as well as a narrow range of differences in the clear-out intervals reported between subjects. It seems that differences in the rates of dissipation of mouth alcohol (both between and within subjects) are small and easily accommodated with the criterion clear-out intervals proposed herein.

The general findings of Experiment 1 agree with those of Dubowski (1975) and contradict those reported by Spector (1971). Data from the present experiment show that BAC estimates were below a clear-out criterion of practical significance within 15 min after expectoration.

The results of Experiment 2 indicate that the rinsing procedure employed in that study was most successful in accelerating the rate of dissipation of mouth alcohol. This finding contradicts Spector's (1971) assertion that rinsing "had only a slight effect" (p. 59) on the rate of dissipation of mouth alcohol. Conceivably, this contradiction may have been a function of methodological differences between the two studies. Spector required his subjects to hold the alcoholic beverage in their mouths from 1 to 4 min; in the present study, subjects retained the alcoholic beverage in their mouths for only 15 sec. Further, while Spector required his subjects to rinse their mouths for a total of 1 to 2 min, the total rinsing time for subjects in the present study was at least 4 min. In Dubowski's (1975) study, subjects were required to retain the alcohol solution in their mouths for 1 min prior to expectoration, and then to undergo two consecutive 30-sec rinsing periods. This procedure was adequate to completely free his subjects of residual mouth alcohol within 8 min of expectoration.

The findings that differences in the rate of mouth alcohol dissipation may be plotted as an inverse function of ethanol concentration and that continuous mouth rinsing with warm water is efficacious in accelerating the rate of mouth alcohol dissipation have definite methodological implications for the conduct of scientific research involving the determination of BAC using breath-analysis procedures. Specifically, these findings suggest that when a continuous rinsing procedure is used, breath testing can be safely conducted within 5 to 7 min following the consumption of a beverage, depending upon the ethanol concentration of the beverage ingested. Consequently, shorter test intervals following alcohol consumption could be used. Such a procedure would substantially decrease the total time necessary to conduct a study requiring BAC measurements by breath analysis. This is particularly relevant when low-peak BACs, about .04%, are used, and when it is important to monitor very closely a subject's BAC even though he/she still may be drinking during the course of the research.

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NOTES

1. Alveolar gas is usually defined as the last gas sample collected at the end of a forced expiration.

2. Registered trade name of the breath-analyzing instrument manufactured by Smith and Wesson Electronics, Springfield, Massachusetts 01101.

3. Registered trade name of the instrument manufactured by Omicron Systems, Inc., Palo Alto, California 94303.

4. Registered trade name of the instrument manufactured by Luckey Laboratories, Inc., San Bernardino, California 92404.

5. Registered trade name of the instrument manufactured by Omicron Systems, Inc., Palo Alto, California 94303.

6. Registered trade name of the instrument manufactured by Luckey Laboratories, Inc., San Bernardino, California 92404.

7. According to the Intoxilyzer operations manual, a reading of up to .003% is within the "zero-set" range for purposes of both calibration and measurement.

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