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Statistical Analysis of Blood- to Breath-Alcohol Ratio Data in the Logarithm-Transformed and Non-Transformed Modes

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Summary: The statistical analysis of non-transformed and logarithm-transformed blood- to breath-alcohol ratios ("blood/breath ratios") is detailed. The data analyzed were derived from 137 simultaneous blood-alcohol and breath-alcohol concentration measurements made between 15 and 179 min after the end of drinking, with 136 of the measurements obtained during the 15- to 124-min time frame. Although the distribution of the non-transformed ratios is positively skewed, and that of the logarithm-transformed data more closely approximates the normal distribution upon visual inspection, both analyses generated results that do not differ significantly from each other when considered in the context of "mean ratios ± 2SD". This is in accord with the results of the *Kolmogorov-Smirnov* goodness-of-fit test, which does not reject either dataset and demonstrates that both are approximately normal. Since the logarithm-transformed data generate more conservative statistical blood/breath ratio ranges than the non-transformed data, they were selected as the basis for the principal conclusion of this work. That conclusion is a refutation of the argument that, breath-alcohol analyzers relying on a 2100 : 1 blood/breath ratio tend to underestimate the blood-alcohol concentrations of driving-while-intoxicated arrestees because the commonly accepted mean postabsorptive ratio is 2300 : 1. In fact, whenever the absorption status of a driving-while-intoxicated arrestee at the time of a breath test cannot be definitively established, the results of this work support the application of a relative error range of −40% to + 28% for 95% of the population, based on a statistical blood/breath ratio range of 1259 : 1 to 2679 : 1, and −46% to + 42% for 99% of the population, based on a statistical range of 1128 : 1 to 2989 : 1.

Introduction

Many biological measurements do not conform to normal error analysis, so that the value of the normal error curve as a descriptive statistic has been challenged (1 : 112). Frequently, however, the initial measurements of a particular random variable may be normally distributed on a different scale, and, as emphasized by *Gaddum* (2), this would result in "an increase in the accuracy and scope of the conclusions drawn from [the measurements]."

An application of this argument was endorsed by *Jones* (3) in 1989 in connection with the calculation of blood/breath ratios from measurements of two random variables, namely blood-alcohol concentrations (BACs) and breath-alcohol concentrations (BrACs). *Jones* recommended that blood/breath ratio data be evaluated on a logarithmic scale, specifically logarithm to base 10. Under these circumstances, if the logarithm of the original variate – in this case, log R, where R denotes the original blood/breath ratio variate – is distributed normally, the distribution would be classified *lognormal*. The use of such a transformation for scientific observations dates back to the work of *Galton* (4), and its characteristics and applications have been detailed in a monograph by *Aitchison & Brown* (5).

The rationale for *Jones'* recommendation was that, while the ratios of blood-alcohol to breath-alcohol concentrations may not be normally distributed, the *differences* between these two varibles on an appropriate scale could very well be, as per the argument of *Finney* (6), whom he cited. Accordingly, the use of the logarithmic transformation would apply because the logarithm of a ratio reflects the *difference* of the logarithms of the two components of the ratio, as can be confirmed from equations 1 and 2.

$$\frac{BAC}{BrAC} = R \qquad \text{(Eq. 1)}$$

Consequently,

$$\log BAC - \log BrAC = \log R \qquad \text{(Eq. 2)}$$

To ascertain the extent to which statistical evaluation of logarithm-transformed blood/breath ratios produces results differing from those generated by the evaluation of the corresponding non-transformed ratios, we have analyzed the blood/breath ratio data of *Giguiere & Simpson* (7). We have chosen to focus on this work because it was designed specifically to emphasize the determination of blood-breath ratios during the first 1 to 2 h after the end of drinking. This is a significant time frame because very few documented studies have employed it.

Those that have done so have used a limited number of test subjects (8, 9) and/or have not tabulated blood/breath ratio data so that it could be subjected to the type of analysis described here (10). Moreover, this time frame is particularly critical in the legal arena because it impacts on the state of alcohol absorption of the drinker, and it can characterize the motor vehicle operator suspected of driving-while-intoxicated who is routinely evaluated within 1 to 2 h after the end of drinking via breath-alcohol testing based on a constant blood/breath ratio, typically 2100 : 1. Given that the generally accepted *mean* postabsorptive blood/breath ratio is about 2300 : 1 (11, 12), and that, therefore, the argument has been offered that breath-alcohol analyzers using the 2100 : 1 conversion tend to underestimate the blood-alcohol concentrations of driving-while-intoxicated arrestees, we consider the statistical analysis of the data of *Giguiere & Simpson* (7) to be crucial to assessing the validity of that argument.

Materials and Methods

The details of *Giguiere & Simpson*'s experimental protocol, including descriptions of test subjects, ethanol administration, blood sampling, and the analytical methods and instruments used, have been presented elsewhere (7). Therefore, only a brief summary is provided here.

A total of 137 blood/breath ratios was determined. These were derived from essentially simultaneous blood-alcohol and breath-alcohol concentration measurements conducted on 79 healthy adults (73 males and 6 females ranging in age from 19 to 68 years) between 15 and 179 min after the end of drinking on an empty stomach. Of these measurements, the first 136 were made between 15 and 124 min after the end of drinking. The test group was comprised of drivers who had records of arrest for driving-while-intoxicated and who had volunteered to participate in a blood/breath ratio study. Blood samples were analyzed via gas chromatographic analysis, and breath samples were analyzed via infrared spectrophotometry, using Intoxilyzer models 4011A, 4011AS, and 5000 (CMI Inc., Minturn, CO, and, currently, Owensboro, KY).

The data analysis for this work, with the exception of the *Geary* kurtosis test (13), was done using the StatView 4.5 statistics program for the Macintosh line of computers (Abacus Concepts, Berkeley, CA). *Geary*'s measure of kurtosis is given by his test statistic, a, and was calculated using equation 3. In this equation – and elsewhere in this article – the standard abbreviation "SD" is used to denote the standard deviation instead of "s", which was used by *Geary* and which appears in many statistical texts; x_i denotes an individual value of either R or log R; and, correspondingly, $\bar{x}$ denotes either $\bar{R}$ (mean R) or log $\bar{R}_G$ (logarithm of the geometric mean, $\bar{R}_G$, where log $\bar{R}_G$ equals the arithmetic mean of the logarithms of the individual Rs).

$$a = \frac{\sum_{i=1}^{n} |x_i - \bar{x}|}{\mathrm{SD}\sqrt{n(n-1)}} \qquad \text{(Eq. 3)}$$

The expected value of a in a normal population is $\sqrt{2/\pi} = 0.7979$. Smaller values indicate leptokurtosis (characteristic of peaked distributions with long tapering tails), and larger values show platykurtosis (indicative of flat-topped distributions with short tails) (14). Critical values of a for random samples from a normally distributed population were tabulated by *Geary* (13), and a more thorough compilation is provided by *Pearson & Hartley* (15). Specifically, for $n = 137$, critical values of a were obtained by linear interpolation on tabulated values (15) – as described by *Snedecor & Cochran* (16 : 541) – for two-sided tests at 2%, 10%, and 20% levels of significance. Thus, for example, the acceptance region for a two-sided test at the 20% level of significance is dictated by the inquality: $a_{0.10} < a_{\text{Experimental Data}} < a_{0.90}$.

Similar inequalities were employed to assess the skewness (g_1) and kurtosis (g_2) test statistics provided by StatView 4.5 at the 2%, 10%, and 20% levels of significance (two-sided), using linear interpolation on tabulated critical values (17 : 326) to obtain the values corresponding to $n = 137$. With regard to g_2, StatView 4.5 yielded results in accord with the equation for kurtosis (16 : 87) that were adjusted by an addition of 3 – which is the expected value for a normal distribution – in order to facilitate comparisons with tabulated critical values. Thus, both values of g_2 and $g_2 + 3$ are reported in this article. In addition, negative kurtosis is indicated by negative values of g_2 ($g_2 + 3 < 3$, platykurtosis), and positive kurtosis by positive values of g_2 ($g_2 + 3 > 3$, leptokurtosis). This pattern is just the reverse of the pattern characterizing the *Geary* kurtosis test, although when applied to the same data, a and g_2 usually produce the same conclusions (16 : 88).

In addition to the measures of skewness and kurtosis described above, the *Kolmogorov-Smirnov* normality test (18–20) was also applied to the data of this work to determine if they deviate from a normal distribution. This test is characterized by the *Kolmogorov-Smirnov* statistic, D, which represents the maximum absolute difference between the sample cumulative distribution and the target cumulative distribution, which, for this work, is the normal distribution.

Results

Table 1 summarizes descriptive statistics for both the non-transformed and logarithm-transformed blood/breath ratio data of *Giguiere & Simpson* (7). Figure 1 depicts histograms with fitted normal curves for the *actual* (a) and *ideal normal* (b) distributions corresponding to the non-transformed data, with the latter figure reflecting the ideal normally distributed values from a distribution having the same mean and SD as the actual data. Figure 2 presents a similar depiction for the logarithm-transformed data. Both figures were generated by StatView 4.5 when it conducted the *Kolmogorov-Smirnov* normality test.

The non-transformed data are positively skewed (fig. 1a, $g_1 = 0.27$). A departure from normality due to skewness occurs barely at the 20% level of significance ($P \approx 0.20$), given that the critical values of g_1 at the 2%, 10%, and 20% levels of significance are ± 0.49, ± 0.34, and ± 0.26, respectively. On the other hand, the kurtosis test shows this data to be more consistent with normality ($g_2 = -0.42$; $g_2 + 3 = 2.58$; $P > 0.20$). The critical values of $(g_2 + 3)_{0.01, 0.05, 0.10}$ are, respectively, 2.26, 2.42, and 2.52, and those of $(g_2 + 3)_{0.99, 0.95, 0.90}$ are, respectively, 4.19, 3.68, and 3.47. The *Geary* kurtosis test, however, is apparently more sensitive in this case because the experimentally derived value of a (0.8241) falls just outside the acceptance region at the 20% level of significance ($P \approx 0.20$), indicating platykurtic behaviour. The critical values of $a_{0.01, 0.05, 0.10}$ are, respectively, 0.7538, 0.7678, and 0.7751, while the critical values of $a_{0.99, 0.95, 0.90}$ are, respectively, 0.8410, 0.8299, and 0.8233.

The distribution of the logarithm-transformed data appears to be more symmetric on visual inspection, and more consistent with the *Gaussian* distribution based on the skewness test (fig. 2a, $g_1 = -0.14$ [$P > 0.20$]). The data do, however, deviate from normality in the direction of platykurtosis at the 20% level of significance ($P \approx 0.20$), since the value of $g_2 + 3$ (2.48) barely falls outside the acceptance region at this level. Interestingly, the *Geary* kurtosis test statistic ($a = 0.8214$) just makes it into the acceptance region ($P > 0.20$).

The arithmetic mean of the non-transformed data (1868 : 1) is not substantially different from the geometric mean (1836 : 1) stemming from the transformed data, with the two means related to each other via equation 4 (1 : 128). This equation yields an essentially unbiased estimate of $\bar{R}$ – denoted by $E(\bar{R})$ – from $\bar{R}_G$; the factor, 1.1513, is equal to (ln 10)/2, and $[SD]^2$ is the sample variance in logarithmic units. The application of equation 4 to the relevant data in table 1 yields a value of $E(\bar{R})$ equal to 1869 : 1, which is essentially identical to the value of $\bar{R}$ provided by StatView 4.5.

$$E(\bar{R}) = \text{antilog}(\log \bar{R}_G + 1.1513[SD]^2) \quad \text{(Eq. 4)}$$

That the logarithmic transformation of the original data produces a distribution which more closely approximates the *Gaussian* distribution, based on visual inspection of figure 2a, can be gleaned from an examination of the individual CVs and medians. Normality is generally improved via logarithmic transformation when the CV exceeds 12% (1 : 112), which is the case with the non-transformed data (CV = 18.7%). Moreover, the greater symmetry of the distribution of the logarithm-transformed data can be ascertained by comparing its median (3.2653) to its mean (3.2639). The two are nearly identical, and the corresponding median R (1842 : 1) and $\bar{R}_G$

Tab. 1 Descriptive statistics for R and log R ($n = 137$)

Statistic	R	log R
Mean	1868 : 1	3.2639[a]
SD	349	0.0820
CV	18.7%	2.5%
Minimum	1190 : 1	3.0755
Maximum	2857 : 1	3.4559
Range of Rs derived from mean ± 2 SD	1170 : 1 to 2566 : 1	1259 : 1 to 2679 : 1
Relative error of mean ± 2 SD compared to R = 2100:1	−44% to + 22%	−40% to + 28%
g_1 (Skewness)	0.27	−0.14
g_2; $g_2 + 3$ (Kurtosis)	−0.42; 2.58	−0.52; 2.48
a (*Geary* kurtosis)	0.8241	0.8214
Kolmogorov-Smirnov normality test: D and P Values	D = 0.051; $P \approx 0.50$	D = 0.051; $P \approx 0.50$
Median	1842 : 1	3.2653

[a] Corresponds to log $\bar{R}_G$, with $\bar{R}_G$ = 1836 : 1.

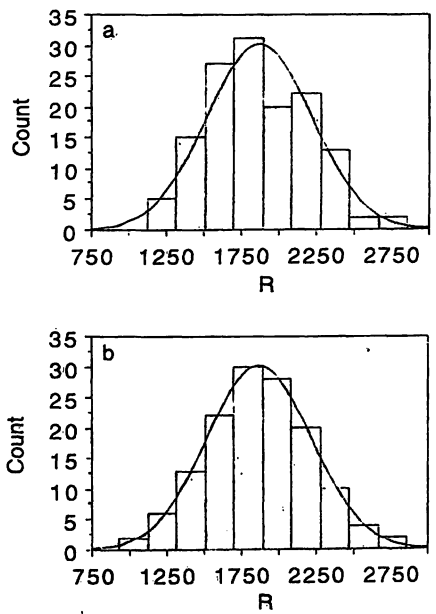

Fig. 1 Distribution histograms with fitted normal curves – generated via application of *Kolmogorov-Smirnov* normality test – for non-transformed blood/breath ratio data (a) of *Giguiere & Simpson* (7) and for corresponding "ideal normal" data (b); blood/breath ratio denoted by R.

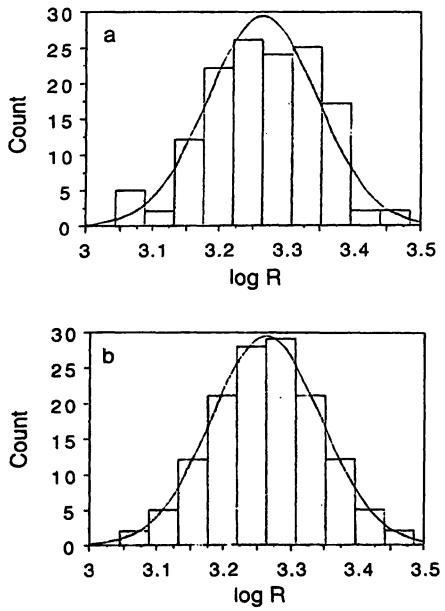

Fig. 2 Distribution histograms with fitted normal curves – generated via application of *Kolmogorov-Smirnov* normality test – for logarithm-transformed blood/breath ratio data (a) of *Giguiere & Simpson* (7) and for corresponding "ideal normal" data (b); blood/breath ratio denoted by R.

(1836 : 1) differ by only 0.3%. In this regard, 70 values of log R are above log $\bar{R}_G$, and 67 values are below, compared to the first and last 68 values of log R that, respectively, lie above and below the value of log R (3.2653) corresponding to median R. In addition, while the minimum and maximum Rs are not uniformly distributed about $\bar{R}$ and deviate from $\bar{R}$ by −1.94 and + 2.83 SD, respectively, the minimum and maximum log Rs deviate from log $\bar{R}_G$ in considerably greater symmetrical fashion, given that the deviations are, respectively, −2.30 and + 2.34 SD. Figures 3a and 3b illustrate the preceding points. These figures are univariate scattergrams of the values of R and log R, respectively, plotted along the horizontal axis in each case in the sequence they appear in their respective datasets. Display lines at the mean and the mean ± 2 SD are also shown.

Despite the above differences regarding deviations from the mean for the non-transformed and logarithm-transformed data, the relative error ranges stemming from a comparison of the standard 2100 : 1 blood/breath ratio with $\bar{R}$ ± 2 SD and with the Rs derived from log $\bar{R}_G$ ± 2 SD, respectively, are not substantially different (−44% to + 22% for the non-transformed data, and −40% to + 28% for the logarithm-transformed data). This is not surprising when considered in the context of the results of the *Kolmogorov-Smirnov* normality test. For both sets of data, a value of D of 0.051 was reported by StatView 4.5, indicating that neither dataset is rejected by the *Kolmogorov-Smirnov* test and that both are approximately normal ($P \approx 0.50$). This P value is consistent with critical values of D associated with the application of the *Kolmogorov-Smirnov* test to samples from which the mean and SD must be estimated, as was done for the datasets of this work (17 : 331, (19, 20)). Thus, logarithmic transformation did not result in a substantial improvement in the degree of normality of the non-transformed data.

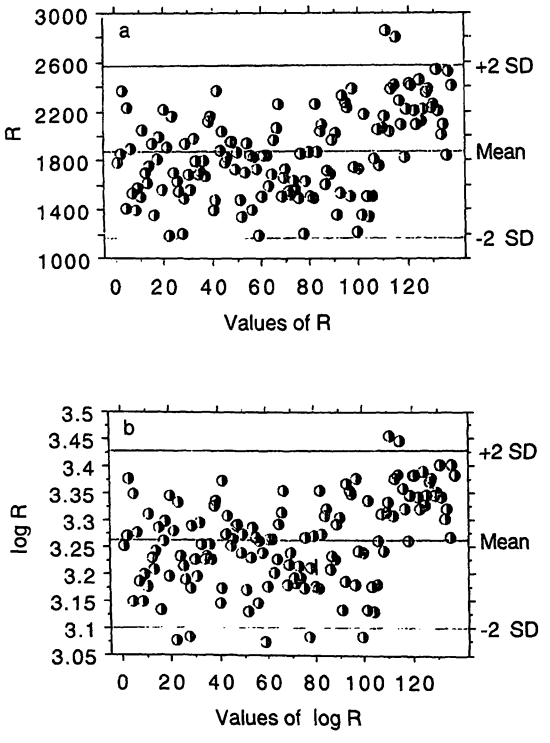

Fig. 3 Univariate scattergram of non-transformed blood/breath ratios (a) and corresponding logarithm-transformed ratios (b) reflecting data of *Giguiere & Simpson* (7); blood/breath ratio denoted by R; each value of R or log R plotted along horizontal axis by StatView 4.5 in the sequence it appears in the dataset (n = 1 to 137).

Discussion

Given the apparent enhanced symmetry of the distribution of the logarithm-transformed data (fig. 2a) compared to the non-transformed data (fig. 1a), and the fact that the former generates statistical blood/breath ratio ranges that are more conservative than those generated by the latter, the following discussion concerning normal error analysis will focus primarily on the logarithm-transformed data. It must be emphasized, however, that normal error analysis can be applied to the non-transformed data as well, given the results of the *Kolmogorov-Smirnov* normality test cited previously. This, together with a consideration of *Chebyshev*'s theorem (17 : 64, 68, (21)), which applies to *any* and *all* distributions of data values, permits a reasonably accurate parametric description of the logarithm-transformed data in terms of its SD and log $\bar{R}_G$.

Chebyshev's theorem — after Russian mathematician *P. L. Chebyshev* (1821−1894) — can be stated as follows (21):

For *any* set of data (either population or sample) and for any constant k greater than 1, the proportion of the data that must lie within k standard deviations on either side of the mean is *at least*

$$1 - \frac{1}{k^2}$$

Alternatively, the corresponding P value for a particular sample, such as the data of this study, can be expressed in the form of *Chebyshev*'s inequality (17 : 64):

$$P(|x_i - \bar{x}| \geq k\,\mathrm{SD}) \leq \frac{1}{k^2}$$

Therefore, the *minimal* fraction of data falling within 2 SD of the mean *must* be 75% ($P \leq 0.25$), and within 3 SD, 88.9% ($P \leq 0.11$). Reference to figure 3b indicates that, for the logarithm-transformed blood/breath ratio data addressed in this work, 130 of the 137 data values (95%) lie within ± 2 SD of log $\bar{R}_G$ (corresponding Rs from table 1, 1259 : 1 to 2679 : 1), which is obviously in accord with *Chebyshev*'s theorem and a distribution that is consistent with a *Gaussian* distribution. (For the less symmetrically distributed non-transformed

data [fig. 3a], 135 of the 137 data values (98.5%) lie within ± 1.94 SD of $\bar{R}$, with a corresponding range of 1190 : 1 to 2545 : 1). Furthermore, virtually all of the transformed data lie within ± 2.30 SD of log $\bar{R}_G$, as noted previously. Within the context of normality, this reflects essentially the central 98% of the population, with a corresponding range of Rs of 1190 : 1 to 2835 : 1, indicating a relative error range of −43% to + 35%, based on the standard 2100 : 1 ratio.

As emphasized by *Rainey* (22), > 95% certainty ($P < 0.05$) is the most common standard of proof used for assessing medical hypotheses, while in criminal proceedings, the well-accepted standard for scientific evidence, namely > 99% certainty ($P < 0.01$), would be more appropriate for meeting the "beyond-a-reasonable-doubt" requirement. This is essentially in agreement with the standard of 99.9% certainty ($P = 0.001$) reported by *Jones* (23) that is employed in Sweden for blood-alcohol concentration determinations based on direct blood analyses. The application of *Rainey*'s argument, therefore, to the logarithm-transformed data of this work, and thus to the central 99% of those data (log $\bar{R}_G$ ± 2.58 SD), would require minimal extrapolation of the range of Rs associated with the central 98% of the data. That extrapolation results in a range of 1128 : 1 to 2989 : 1, which is equivalent to an adjustment of the former range by about ± 5%. The relative error range in this case, based on 2100 : 1, would be a nearly symmetrical −46% to + 42%.

While *Heifer* (10) determined blood/breath ratios for 133 subjects between 15 and 270 min after the end of drinking − using the evidential breath-alcohol analyzers, Alcotest 7010 (Draeger) and Alcomat (Siemens), an ethanol dose of 0.5−1.0 g/kg bodyweight, and a consumption time of 10−90 min − he did not tabulate his data, as indicated previously. Nevertheless, estimates can be made from his graphed results which can be compared with the results obtained from the analysis of the non-transformed data of *Giguiere & Simpson* (7). *Heifer* summarized his data in a plot of BrAC/BAC *v* time after the end of drinking (fig. 1 of his article), so that, based on the standard 2100 : 1 ratio, a value of R can be estimated from this plot by calculating the product of 2100 and the reciprocal of a relevant BrAC/BAC value. He included values of $\bar{R}$ reflecting a total of 1150 paired blood and breath specimens − which represent the greatest number of blood/breath pairs ever reported in a laboratory study − at 15 (119 pairs), 30 (116 pairs), 60 (109 pairs), 90 (103 pairs), 120 (102 pairs), 150 (133 pairs), 180 (132 pairs), 210 (113 pairs), 240 (108 pairs), and 270 min (115 pairs) after the end of drinking. Also included at each of these times were the data points corresponding to $\bar{R}$ ± 2 SD. Since 136 of the 137 measurements analyzed in our work were obtained between 15 and 124 min after the end of drinking, and since omission of the 137th measurement (2415 : 1) taken at 179 min would have had virtually no effect on the results generated from statistical analysis of the overall data, estimates made from *Heifer*'s work for comparison with our results were restricted to his 15- to 120-min time frame. Under these conditions, the following estimates can be made from figure 1 of *Heifer*'s article (It should be noted that *Heifer* confirmed − via written communication to *Simpson* in May, 1993 − our interpretation of and the estimates made from figure 1, and that his blood/breath ratio data conform closely to a *Gaussian* distribution.): $\bar{R} \approx 1780 : 1$; SD ≈ 350; CV ≈ 20%; $\bar{R}$ ± 2 SD ≈ 1080 : 1 to 2480 : 1 (relative error range, based on 2100 : 1: −49% to + 18%).

A comparison of these results with those derived from the non-transformed data of *Giguiere & Simpson* (7) indicates that the latter are more conservative, but not substantially so, given that the corresponding relative error range for the *Giguiere/Simpson* data is −44% to + 22%. Moreover, since the CV associated with *Heifer*'s data exceeds 12%, logarithmic transformation would be expected to improve the normality of the distribution of that data (1 : 112). Nevertheless, the message stemming from the above analysis of *Heifer*'s data is consistent with the message of this work, which is summarized in the following conclusion.

Conclusion

As has been reported earlier (8−11), the magnitude of the blood/breath ratio is dependent on the time elapsed after the end of drinking. Nearly all of the data analyzed in this work (99.3%, or 136 of 137 measurements) were obtained between 0.25 and 2.07 h after the end of drinking. This period has been characterized as the absorptive/plateau phases of alcohol metabolism, or the time required to reach peak blood-alcohol concentration (11). In this regard, *Baselt & Danhof* (24) reported that, for fasting subjects, 0.5 to 2.1 h after the end of drinking must elapse before peak blood-alcohol concentration is reached. Certainly the factor of food consumption, including the type and quantity of food eaten, would contribute to an extension of both the lower and upper bounds of these ranges, as confirmed by *Baselt & Danhof* (24). For non-fasting subjects, they specified a time-to-peak blood-alcohol concentration range of 1.0 to 6.0 h. In addition, *Dubowski* (11) summarized data from his experiments conducted on both female and/or male subjects that were consistent with the conclusions of *Baselt & Danhof*. *Dubowski* also emphasized that, in addition to the factor of food consumption, the rate of alcohol absorption is dependent on other factors, including the type and concentration of alcoholic beverage ingested, and a "multitude of other physical, biological, psychological and time factors ... [and] the individual's

sex, body weight and body water, and related habitus characteristics as well as offsetting metabolic disposition."

Under field conditions, the driving-while-intoxicated arrestee's absorption status at the time of the breath test is generally unknown. Clearly, the time frame 0.25–2 h after the end of drinking is important, although it is often difficult to identify the point in this time frame characterizing a particular arrestee when his/her breath test is administered. Therefore, as emphasized below, this overall general time frame is best used to characterize the absorption status of a driving-while-intoxicated arrestee when that status is unknown. Nevertheless, given the dependence of the blood/breath ratio on the time elapsed after the end of drinking, figure 1 of *Heifer*'s article (10), which reflects non-transformed data that is clearly more extensive than the corresponding data of this work, can be used to assess the variability of the blood/breath ratio according to the five specific times comprising *Heifer*'s 0.25–2 h time frame. Thus, his estimated values of $\bar{R}$ and associated parenthetical values of SD at 15, 30, 60, 90, and 120 min after the end of drinking are, respectively, 1365 : 1 (320); 1680 : 1 (365); 1910 : 1 (365); 1945 : 1 (355); 2020 : 1 (330).

Whenever it can be established by objective means that a driving-while-intoxicated arrestee is "fully postabsorptive," then the blood/breath ratio data summarized by *Dubowski* (11), which reflect the results of a study he conducted with *O'Neill* (25) on healthy, "fully postabsorptive" males, may be applicable. (In this regard, *Dubowski* [11] did not thoroughly define the label, "fully postabsorptive"; that is, he did not specify how much time after peak blood-alcohol concentration was required before subjects were deemed fully postabsorptive, nor did he specify the blood-alcohol or breath-alcohol concentrations involved.) That study produced an $\bar{R}$ of 2280 : 1 (SD = 241.5, CV = 10.6%) derived from analysis of 393 paired blood and breath specimens. *Dubowski* stated explicitly that the data "have a *Gaussian* distribution" and reported a range of 1555 : 1 to 3005 : 1 (± 3 SD) for 99.7% of the population (relative error range, based on 2100 : 1: −26% to + 43%). For 99% of the population (± 2.58 SD), as per *Rainey*'s stipulation (22), the range would be narrowed slightly to 1657 : 1 to 2903 : 1 (relative error range: −21% to + 38%). Logarithm-transformation of this data would not be expected to result in a significant improvement in normality because, given a CV of 10.6%, such improvement, as noted previously, generally occurs when the CV exceeds 12% ((1), p. 112).

If, on the other hand, a driving-while-intoxicated arrestee's absorption status is unknown, and he/she is to be given the benefit of the doubt, then the results of the present work are applicable, as indicated previously. At the very minimum, the relative error range listed in table 1 for the range of Rs derived from log $\bar{R}_G$ ± 2 SD (−40% to + 28%, based on 1259 : 1 to 2679 : 1) should apply, and for 99% of the population, reflecting log $\bar{R}_G$ ± 2.58 SD, the applicable relative error range would be −46% to + 42%, based on 1128 : 1 to 2989 : 1.

In the final analysis, the recommendations offered here are consistent with *Dubowski*'s assessment of the generally accepted mean postabsorptive blood/breath ratio of approximately 2300 : 1 (11): "significant variations from this population mean exist during active alcohol absorption and in some individuals even in the postabsorptive phase." This article quantifies the errors produced by such variations when estimates of blood-alcohol concentration are made by means of breath-alcohol analysis. Moreover, the statistical analysis presented here indicates there is little merit to the claim that, because of skewing, it is inappropriate to apply normal error analysis to blood/breath ratios to estimate error limits at the 95 and 99% confidence levels. In this regard, while use of a logarithmic transformation of blood/breath ratio data is the basis for the principal conclusions of this article, the results of this work indicate that the non-transformed data can also provide useful estimates of the amount of error expected in breath test results.

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