The Top 20 Myths Of Breath, Blood, And Urine Tests — Part 1

By Leonard R. Stamm

When the experts disagree, who are we to believe? As Learned Hand observed:

> The whole object of the expert is to tell the jury, not facts . . . but general truths derived from his specialized experience. But how can the jury judge between two statements each founded upon an experience confessedly foreign in kind to their own? It is just because they are incompetent for such a task that the expert is necessary at all.

Learned Hand, *Historical and Practical Considerations Regarding Expert Testimony*, 15 HARV. L. REV. 40, 53 (1901).

This article explores disagreements among the experts — the myths commonly employed by courts, police, and prosecutors, and often accepted by defense lawyers in drunk driving cases, and the published scientific articles debunking those myths. In some cases, there is honest debate about the validity of the state's methods and theories. In other cases, the state's experts' conclusions are translated improperly by police and prosecutors, to the detriment of defendants. The point of this article is not to comprehensively discuss every point of view, but to quote some of the published scientific articles that challenge the status quo.

Most of these articles cannot be found in a law library or on Westlaw or Lexis. One major resource for exploring scientific literature related to drunk driving is *www.pubmed.com*. While this is an excellent resource for reading abstracts of the articles, unless one subscribes to the relevant scientific journals, it is often necessary to do research "the old fashioned way" and copy these articles at a medical library. There are also innumerable scientific texts covering our subject, many of which were excellent resources in writing this article. Among them, MEDICAL-LEGAL ASPECTS OF ALCOHOL, (James G. Garriott ed., 4th ed. 2004), contains articles by the leading experts in the field, including Dr. A.W. Jones and Dr. Kurt Dubowski. A legal treatise that discusses some of the scientific literature in depth is Edward F. Fitzgerald, *Intoxication Test Evidence* (2nd. ed.).[1]

Most of the articles discussed here have been "peer reviewed." Peer review "increases the likelihood that substantive

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flaws in methodology will be detected." *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579, 593-94 (1993). It refers to a process of editing. Kenneth K. Altman, *The Myth of "Passing Peer Review," in Ethics and Policy in Scientific Publication* 257, 262 (Council of Biology Editors, Inc. 1990). Scientific publication is not immune to falsification of data, plagiarism, conflict of interest, and politics. *Id.* Most commentators agree that the quality of published scientific articles is enhanced by peer review. However, how much is anyone's guess and differs from journal to journal.

Certainly the author's background and past and present affiliations may be relevant to an evaluation of him or her. Many of the published researchers in the field of forensic toxicology related to alcohol testing are presently or were formerly employed by, or affiliated with, state alcohol testing programs. While this does not necessarily create a conflict of interest, it may indicate a bias that is relevant to an assessment of an article's credibility or an author's testimony in court.

Finally, it is important to recognize that many scientific articles rely on the language of statistics in reaching their conclusions. Statistical concepts are often not well translated into legal concepts, like the concept of proof beyond a reasonable doubt. This allows the state to employ a mathematical slight of hand, using a preponderance standard to secure admission of test results and then arguing that they have satisfied the higher standard of proof beyond a reasonable doubt.

It is with these considerations in mind that we turn now to the top 20 myths in breath, blood, and urine testing.

Myth #1: Breath Means Alveolar Air

The alcohol breath test is the most commonly used form of alcohol testing evidence in drunk driving prosecutions. Many articles praise the breath test as a highly accurate and reliable means of testing the amount of alcohol in the alveolar air of a person at the time of the test, assuming certain safeguards are met. *E.g.*, Kurt M. Dubowski, *Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects*, 10 J. STUD. ALCOHOL SUPPL. 98 (1985).

Forensic toxicologists have long assumed that a properly obtained breath alcohol sample contains alveolar air. However, in most statutes, both "blood" and "breath" are undefined. Blood can be venous, arterial, capillary, or from any other part of the body. Breath can be upper, lower respiratory, or mouth. "Blood" and "breath" were left undefined because state scientists did not want to legislate requirements that would be difficult to implement in practice and difficult for the government to prove. Significantly, although breath statutes rest on the belief that the exchange of alcohol from the blood to the breath occurs in the alveoli, they do not require a sample of exclusively alveolar or deep lung air.

It is claimed that the failure to obtain a solely alveolar sample does not prejudice the defendant.

> It should be noted that alveolar air is not required. Inasmuch as in an otherwise correctly performed breath test, failure to obtain air *only* of alveolar composition gives a nearly proportionately lower result and is without prejudice to the defendant, the question of the specimen being entirely alveolar in origin need not arise.

Morton F. Mason, & Kurt M. Dubowski, *Breath as a Specimen for Analysis for Ethanol and Other Low-Molecular-Weight Alcohols*, MEDICAL-LEGAL ASPECTS OF ALCOHOL 177, 178 (James C. Garriott ed., 4th ed. 2003).

This is an example of scientists and lawyers using language in different ways. Although the scientists may have assumed that alveolar air is preferred for an accurate test, the law does not say that. Instead, because "breath" is undefined, the only logical interpretation of the statute is that "breath" means the whole breath. A dictionary definition of breath is "air inhaled and exhaled in breathing." MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY, (11th ed. 2004). If the legal level is determined by reference to the entire breath, alveolar air is only a portion of that breath. If alveolar air contains a higher concentration of alcohol than the whole breath, then a tested sample of alveolar air will give a false high reading of the whole breath required by the statute.

Recent articles by Dr. Michael Hlastala of the University of Washington show that alveolar air does not accurately relate to the blood level because the exchange of alcohol from blood to the breath in the lung occurs in the upper airway, not the alveoli.

> Calculations by Anderson show that, whereas gases with blood-air partition coefficients (λ) of <1 exchange entirely in the alveoli, gases with higher solubility (λ of > 10) also exchange within the airways. Gases with λ of >400 exchange entirely in the pulmonary airways, not within the alveoli. Exhaled BrAC originates entirely from the airway mucus and tissue (perfused by the systemic bronchial circulation).

Michael P. Hlastala, *Invited Editorial on "The Alcohol Breath Test,"* 93 JOURNAL OF APPLIED PHYSIOLOGY 405, 405 (2002).

He also notes a measured blood-breath ratio that is lower than the one used by breath test instruments.

> Jones measured the equilibrium by using an in vitro equilibration chamber with controlled temperature. In that study, the partition between blood and air at 37ºC was measured at 1,756 ± 8 (mean ± SE) at 37ºC. Thus there is a 20% discrepancy between the directly measured partition ratio (1,756) and the blood-breath ratio (2,100) (2,100/1,756 ~ 1.2). This difference can be explained by an average loss of alcohol to the airway mucosa in the average ABT of ~ 20%.

Id. at 405.

Hlastala also challenges the notion that breath test instruments will necessarily obtain an accurate reading of the alveolar air.

> [T]he notion that a flat slope will always be obtained when expiratory flow rate approaches zero and that this represents alveolar air is incorrect. . . . At the end of exhalation, BrAC levels off when flow decreases, irrespective of the exhaled volume. The flat slope does not indicate the presence of air at alveolar concentration because BrAC is an increasing function with exhaled breath volume.

Michael P. Hlastala, *The Alcohol Breath Test — A Review*, 84 (2) JOURNAL OF APPLIED PHYSIOLOGY 401, 402-03 (1998).

He thus concludes that breath test instruments currently in use tend to favor individuals with larger lung size, because those individuals may stop breathing into the machine earlier, allowing the machine to be fooled into sampling a nonalveolar portion of the breath that is lower in alcohol concentration.

> A consequence of continuing to

> use the old model is that subjects with larger lung volume may have a lower BrAC than a subject with a small lung volume because these subjects do not need to exhale as great a fraction of their vital capacity as subjects with smaller lung volume to fulfill the minimum volume exhalation required before stopping exhalation (usually ~1.5 liters). A person with smaller lung volume must breathe farther into the exhaled breath, resulting in a greater BrAC-to-BAC ratio.

Michael P. Hlastala., *Invited Editorial on "The Alcohol Breath Test,"* 93 JOURNAL OF APPLIED PHYSIOLOGY 405, 406 (2002).

This revolutionary proposition, that the alcohol exchange between the blood and air occurs in the upper airways, is what Dr. Hlastala calls his new paradigm. It should be noted that his field of expertise is lung physiology, not toxicology.

Myth #2: Breath Test — DUI Suspects Are Post-Absorptive

At least one court opinion boldly states, "Because any delay in the administration of a chemical test ordinarily inures to the benefit of the accused, an accused suffers no prejudice." *Willis v. State*, 488 A.2d 171, 180 (Md. 1985). This statement assumes that the person was post-absorptive at the time of driving and testing. It ain't necessarily so.

Studies by Kurt M. Dubowski indicate varying ranges of elapsed time from the end of alcohol intake to peak blood alcohol concentration of 14 to 138 minutes, 9 to 114 minutes, and 12 to 166 minutes. Kurt M. Dubowski, *Absorption, Distribution and Elimination of Alcohol:Highway Safety Aspects*, 10 J. STUD. ALCOHOL SUPPL. 98-105 (July 1985). He concludes:

> It is often impossible to determine whether the postabsorptive state has been reached at any given time. Those factors make it impossible or infeasible to convert the alcohol concentration of breath or urine to the simultaneous blood alcohol concentration with forensically acceptable certainty, especially under per se or absolute alcohol concentration laws.

Id. at 105.

Myth #3: Breath Test — Absorptive Phase Test Is Okay

A number of articles report a *huge* disparity between measurements of breath alcohol and venal blood alcohol content when the person being tested is still absorbing the alcohol into his or her body, or is in the absorptive phase of alcohol metabolism. One study showed that the breath result can be as much as 100 percent higher than the blood level during the absorptive phase. E. Martin, W. Moll, P. Schmid, L. Dettli, *The Pharmacokinetics of Alcohol in Human Breath, Venous and Arterial Blood After Oral Ingestion*, 26 (5) EUR. J. CLIN. PHARMACOL., 619 (1984).

Other studies also report unacceptably high differences between breath and blood results obtained during the absorptive phase. *E.g.*, G. Simpson, *Accuracy and Precision of Breath Alcohol Measurements for Subjects in the Absorptive State*, 33(6) CLIN. CHEM. 753 (June, 1987); G. Simpson, *Corrections to a Report*, 33(11) CLIN CHEM 2130 (Nov. 1987) (erratum to the June article); G. Simpson, *Do Breath Tests Really Underestimate Blood Alcohol Concentration?* 13(2) JOURNAL OF ANALYTICAL TOXICOLOGY, 120 (Mar.-Apr. 1989). Dr. Simpson's conclusions speak for themselves.

> Simultaneous measurements of breath alcohol concentration (BrAC) and venous blood alcohol concentration (VBAC) show that actual VBAC can be overestimated by more than 100% for a significant amount of time after drinking stops. The maximum error for four individual subjects is +230%, +190%, +60%, and +30%. The magnitude of these errors indicates that results from quantitative evidential breath alcohol analyzers are far less accurate for the absorptive state than the postabsorptive state, but the specifications for accuracy and precision given by manufacturers of these instruments do not reflect this.

G. Simpson, *Accuracy and Precision of Alcohol Measurements for Subjects in the Absorptive State*, 33 (6) CLIN. CHEM. 753, 753 (1987). He continues:

> The results also indicate that there is a significant likelihood that subjects will be in the absorptive state when tested under field conditions. I conclude that estimates of BAC based on BrAC measurements are not reliable in the absorptive state and that the uncertainty associated with such estimates should be accounted for, particularly when the results are used in connection with law enforcement.

Id. at 753.

Myth #4: Breath Test — 2100:1 Favors Your Client

State scientists claim that the 2100:1 blood-breath partition ratio favors defendants because the true mean is closer to 2300:1.

> Breath alcohol analysis is by far the most commonly employed form of chemical testing in traffic law enforcement. Hence the true blood:breath ratio for alcohol, originally used to calibrate alcohol analyzers to indicate the supposedly corresponding blood alcohol concentration, has been a subject of much scientific investigation and debate for about 50 years. It is evident from considerations of quantitative human biology that a single ratio or conversion factor will not apply to all persons (Mason and Dubowski, 1974, 1976).

Kurt M. Dubowski, *Absorption, Distribution and Elimination of Alcohol: Highway Safety Aspects*, 10 J. STUD. ALCOHOL SUPPL. 98, 102 (1985).

> Nevertheless, for half of that period, there was general acceptance of 2100:1 as the partition ratio of alcohol between blood and alveolar breath, as a population mean (Borkenstein et al. 1972; Harger et at., 1950; National Safety Council, 1953). Quantitative evidential breath alcohol analyzers are still currently factory-calibrated in grams of alcohol per 210 L of breath. Some official guidelines incorporate this calibration (National Highway Traffic Safety Administration, 1984), thus in effect retaining a 2100:1 blood alcohol:breath concentration ratio for those jurisdictions statutorily requiring the reporting of evidentiary alcohol concentrations in terms of blood.

Id. at 101-102.

> Later studies on larger subject groups, with more sophisticated chemical analyses of blood and breath for alcohol and more extensive data treatment, indicated that the mean alcohol partition factor between blood and breath is very close to 2300:1 (Dubowski, 1975; Dubowski and O'Neill, 1979; Jones, 1976; Jones et al., 1975). However, significant variations from this population mean exist during active alcohol absorption and in some individuals even in the post-absorptive phase. The typical biological variability of human alcohol pharmacokinetic parameters is well illustrated by the data from studies of Dubowski and O'Neill (1979). These are summarized in Table 3, for the ratio of alcohol concentrations in whole blood and end-expiratory breath in healthy adult men in the fully postabsorptive phase.

Id. at 102.

> These experimentally determined ratios have a Gaussian distribution. Hence a postabsorptive blood alcohol: breath alcohol concentration ratio range of 1797:1 to 2763:1 can be estimated for 95% and 1555:1 to 3005:1 for 99.7% of such a population.

Id. at 102.

Transposing Dr. Dubowski's figures onto a normal or Gaussian[2] distribution chart makes it easier to conceptualize his findings (*See* Figure below).

While 2300:1 is slightly greater than the mean of 2280:1, 2100:1 or higher accounts for less than 80 percent of the total population. Thus over 20 percent of persons tested in this study would have a false high reading at 2100:1. In order to achieve a confidence level of 99.7 percent, the partition ratio of 1555:1 would have to be used.

Myth #5: Breath Test — Reporting BAC As BrAC Cures Blood: Breath Ratio Problems.

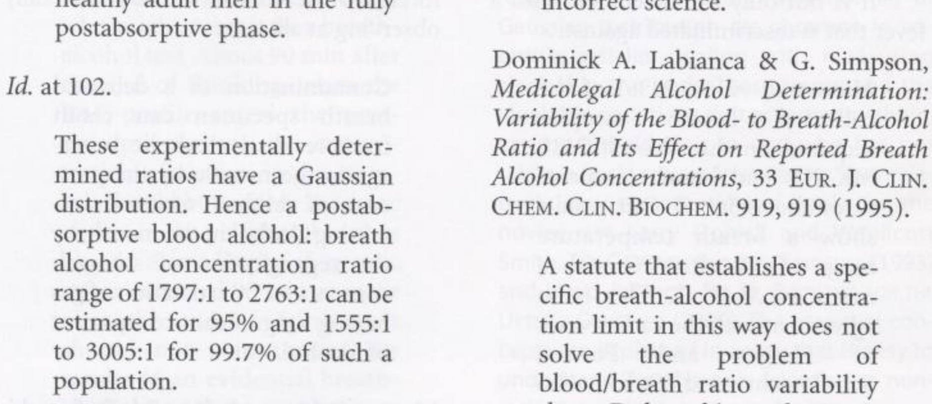
Again, Dr. Simpson needs no interpretation.

> The enactment of direct breath-alcohol statutes, however, has not eliminated the need to correct for the experimental error stemming from the conversion of breath- into blood-alcohol concentration via multiplication of the former by a constant blood/breath ratio. In fact the enactment of such statutes has . . . resulted in the legislation of incorrect science.

Dominick A. Labianca & G. Simpson, *Medicolegal Alcohol Determination: Variability of the Blood- to Breath-Alcohol Ratio and Its Effect on Reported Breath Alcohol Concentrations*, 33 Eur. J. Clin. Chem. Clin. Biochem. 919, 919 (1995).

> A statute that establishes a specific breath-alcohol concentration limit in this way does not solve the problem of blood/breath ratio variability that Dubowski and Jones sought to eliminate. It simply ignores that variability, which is the essence of its scientific flaw.

Id. at 919-20.



> Moreover, since the statute operates under the assumption that any driving-while-intoxicated suspect who undergoes a breath test is characterized by a 2100:1 blood/breath ratio, it is also legally flawed; if the statute does 'greatly enhance the investigation and disposition of [driving while intoxicated] charges'; as claimed by Dubowski, it does so by inappropriately relieving the prosecution of its burden to establish that the defendant has a blood/breath ratio of 2100:1 at the time of the breath test.

Id. at 920-921.

> [T]he only approach at present is to use population data for blood/breath ratios corresponding to appropriate confidence limits. As recently stated by Rainey . . . mean ± 2.58 SD (99% confidence limits) is the appropriate confidence interval for conversions of body-fluid alcohol concentrations when a standard of 'beyond a reasonable doubt' is required.

Id. at 921.

Applying the 2.58 standard deviation concept for 99 percent reliability, using Dr. Dubowski's figures, a reported BrAC (breath alcohol concentration) of .10 would instead be reported as .0789.[3]

Myth #6: Breath Test — Temperature Does Not Need To Be Measured

In all but a small number of jurisdictions, breath temperatures are not accounted for by the breath testing machines in use. Breath test devices are calibrated and checked with solutions heated to 34° C. If the defendant's breath is higher than 34° C, the test reading will be falsely elevated.

> As temperatures rise, the concentration of ethanol in the air phase increases and therefore the blood/air partition coefficient decreases. The average temperature coefficient of solubility for dilute solutions of ethanol in water and blood is 6.5% per 1° C for the temperature range of 20-40° C.

A.W. Jones., *Effects of Temperature and Humidity of Inhaled Air on the Concentration of Ethanol in a Man's Exhaled Breath*, 63 CLINICAL SCIENCE 441, 441 (1982), *citing*, Kurt M. Dubowski, *Breath-alcohol Simulators: Scientific Basis and Actual Performance*, 3 JOURNAL OF ANALYTICAL TOXICOLOGY 177 (1979).

> These results show clearly that mild hyperthermia in humans does . . . significantly distort the BrAC decay curve to an extent which would cause serious inaccuracy for prediction of BAC. The magnitude of this distorting effect of core temperature is too large (up to 23% with mild hyperthermia) to be ignored in breath-testing procedures. . . . [S]uch error in the case of hyperthermia increases the likelihood of a suspect being unjustly convicted.

Glyn R. Fox & John S. Hayward, *Effect of Hyperthermia on Breath Alcohol Analysis*, 34 (4) JOURNAL OF FORENSIC SCIENCES 836, 839 (1989).

It is not only the defendant with a fever that is discriminated against.

> Almost all (93%, 81%) of the collected breath samples acquired on the Alcotest 7110 MK IIIs had breath temperatures above 34° C. Our results show a breath temperature range of 32.4-36.2° C with a mean of 34.9° C. This is in agreement with the earlier work of Harger and Forney, Schoknecht and Stock who found mean breath temperatures of 35.1° C and 35° C, respectively.

Dale A. Carpenter & James M. Buttram, *Breath Temperature: An Alabama Perspective*, 9 IACT NEWSLETTER 16, 16 (July, 1998). If Alabama defendants are indicative of defendants generally, then between 81 percent and 93 percent of breath tests nationwide are falsely elevated on the basis of temperature alone.

Myth #7: Breath Test — Breathing Pattern Is Not Important

Breathing pattern is another factor where different operator techniques can lead to disparate results.

> With breath holding (30 seconds) before expiration, the concentration of ethanol increased by 15.7 ± 2.24 percent (mean ± SE) and the temperature of breath rose by 0.6 ± 0.09° C. . . . Keeping the mouth closed for 5 minutes (shallow breathing) increased expired ethanol concentration by 7.3 ± 1.2 per cent and the breath temperature rose by 0.7 ± 0.14° C. After a slow (20 second) exhalation expired ethanol increased by 2.0 ± 0.71 percent but breath temperatures remained unchanged from control tests.

A.W. Jones, *How Breathing Technique Can Influence the Results of Breath-Alcohol Analysis*, 22 (4) MED. SCI. LAW 275, 275 (1982).

Myth #8: Breath Test — Belching Cannot Affect A Breath Test

Breath test operators often let arresting officers untrained in obtaining a breath sample observe the defendant for a portion of the 15 or 20 minute deprivation period. The problem is that the arresting officers may only be looking for foreign object intake, if they are really observing at all.

> Contamination of a delivered breath specimen can result from residual alcoholic beverage in the mouth, by the presence of residual vomitus containing alcohol in the mouth, by the regurgitation of stomach contents, or by eructation of gas having a significant component of alcohol.

Morton F. Mason & Kurt M. Dubowski, *Breath as a Specimen for Analysis for Ethanol and Other Low-Molecular-Weight Alcohols*, MEDICAL-LEGAL ASPECTS OF ALCOHOL 177, 180 (James C. Garriott ed., 4th ed. 2003). "Eructation" is defined as "an instance of belching." MERRIAM-WEBSTER'S COLLEGIATE DICTIONARY, (11th ed. 2004).

> Alcohol in the oral cavity arising from recent alcohol ingestion, regurgitation of stomach contents containing alcohol or by eructation of gas containing sufficient amounts of alcohol can contaminate the breath sample and cause falsely elevated results.

Patrick Harding, *Methods for Breath Analysis*, MEDICAL-LEGAL ASPECTS OF ALCOHOL 185, 186 (James C. Garriott ed., 4th ed. 2003).

> The pioneer work by Bogen indicated that hiccuping, burping, and belching might present a problem in connection with breath-alcohol analysis. Only very limited investigations of this problem have been made, but these indicate that the risk of elevating breath-alcohol readings is greatest shortly after the end of drinking as might be expected because the concentration of alcohol in the stomach is then at its highest.

Alan Wayne Jones & Barry K. Logan, *DUI Defenses*, DRUG ABUSE HANDBOOK 1006, 1024 (Steven B. Karch ed., 1988).

Myth #9: Breath Test — GERD Cannot Affect The Breath Test

> It was reported that approximately 7% of US adults experience daily heartburn so GERD probably represents a common disorder, even among those who might submit to a breath-alcohol test. About 90 min after the end of drinking, when the BAC-profile enters the post-absorptive phase, the concentration of alcohol in the stomach should be roughly the same as that in the peripheral venous blood. Accordingly, if gastric reflux occurred 90 min or more after the end of drinking it should not compromise the results of an evidential breath-alcohol test because the concentration of alcohol in the gastric fluid at this time is relatively low and probably similar to that of mucous secretions in the mouth and upper-airway.

Stergios Kechagias, Kjell-Ake Jonsson, Thomas Franzen, Lars Andersson & Alan Wayne Jones, *Reliability of Breath-Alcohol Analysis in Individuals with Gastroesophageal Reflux Disease*, 44 (4) J. FORENSIC SCI. 814, 814 (Jul. 1999).

Of course, this quote implies that the converse may be true. If the gastric reflux occurs during absorption, which according to studies by Dr. Dubowski cited above, can take over 2 1/2 hours, then it could affect the breath reading.

> Obviously, the risk of gastric reflux increasing the result of a breath-alcohol test will be greatest shortly after the end of drinking when the concentration of alcohol in the stomach is at its highest. [T]he mandatory 15 min observation period still remains an important element of the evidential breath-alcohol test protocol because this can help to rebut allegations that gastric reflux occurred.

Id. at 818.

Notes

1. Other legal treatises containing helpful information include Paul C. Gianelli and Edward J. Immwinkelreid, SCIENTIFIC EVIDENCE, (3rd ed. 1999), Lawrence Taylor, DRUNK DRIVING DEFENSE (New York: Aspen Law and Business 5th ed. 2000), Don Nichols and Flem Whited, DRINKING/DRIVING LITIGATION CRIMINAL AND CIVIL (2nd ed.1998), John Tarantino, DEFENDING DRINKING DRIVERS, (Heidi Lowry and Erin Tackitt eds., rev. 20 2004) and Richard Erwin, DEFENSE OF DRUNK DRIVING CASES, CRIMINAL AND CIVIL (2nd ed. 2004).

2. Terms like "standard of deviation," "coefficient of variation," and normal or Gaussian distribution are common in scientific articles dealing with measuring alcohol in the body. These terms, and the algebraic equations that accompany them, can be intimidating to one who has not taken a basic course in statistics. Two relatively easy to comprehend books for the novice are Larry Gonick and Woollcott Smith, THE CARTOON GUIDE TO STATISTICS (1993) and Lloyd Jaisingh, Ph. D., STATISTICS FOR THE UTTERLY CONFUSED (2000). The essential concepts are explained in a way that is easy to understand for the non-scientist or non-statistician. In other words, lawyers can comprehend these books!

In a sample population, the standard deviation or "s" is the average deviation from the mean. The mean, or average, is the sum of all of the samples divided by the number of samples. Each sample is then subtracted from the mean and squared. The sum of the squares of the differences is divided by the number of samples minus 1. The square root of that number is the standard deviation. Simple, right?

Let's take a sample composed of 8 numbers: 10; 12; 14; 15; 17; 18; 18; and 24. The sum of these numbers is 128. 128 divided by 8 equals the mean or 16. 10 minus 16 equals -6. -6 squared equals 36. This is repeated for each number. So the number, difference from the mean and square of the difference for each remaining number in the sample is 12, -4, 16; 14, -2, 4; 15, -1, 1; 17, 1,1; 18, 2, 4; 18, 2, 4; and 24, 8, 64. These squares are all added. 36+16+4+1+1+4+4+64 for a total of 130. That total is divided by the number of numbers in the sample minus 1 or 8-1 or 7. 130 divided by 7 equals 18.57142. The square root of that is 4.309. That is the standard deviation. Voila! We are now statisticians!

The coefficient of variation is the relation between the standard deviation and the mean, expressed as a percentage. In our sample, for example, the standard deviation of 4.309 divided by the mean, 16, times 100, and expressed as a percentage is 26.934 percent.

A normal or Gaussian distribution is basically a bell curve, where the greatest number of numbers in the sample are closest to the mean and drop off as they are further from it. It is named for Johann Carl Friedrich Gauss, a 17th-century mathematician who is credited with having first recognized this concept. In a population with a Gaussian distribution, as you move away from the mean in both directions, generally 68.2 percent of the population will be within one standard deviation from the mean, 95.5 percent of the population will be within 2 standard deviations and 99.7 percent of the population will be within 3 standard deviations from the mean.

3. This is computed by multiplying the standard deviation of 241.5 x 2.58 = 623.7. Subtracting this figure from 2280 equals 1656.93. Thus the partition ratio of 1656.93 is reached for a confidence level of 99 percent.

About the Author

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