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Precision of Breath Alcohol Testing in the Field Using
the Intoxilyzer® 5000C and the Paradox of Truncation

by
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PRECISION OF BREATH ALCOHOL TESTING IN THE FIELD USING THE INTOXILYZER® 5000C AND THE PARADOX OF TRUNCATION¹

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ABSTRACT

In a retrospective study, Intoxilyzer® 5000C results obtained over a four year period by qualified breath technicians of the Toronto Police Services (TPS) between 1995 and 1998 were analysed and compared for the precision between untruncated and truncated duplicate breath tests. A total of 8585 breath tests were analysed. Of these, 8309 (97%) were found to be within 20 mg/dL untruncated, versus 276 (3%), that were within 21 to 29 mg/dL. The mean absolute (unsigned) difference between subject tests that were within 20 mg/dL untruncated for all four years was 7.05 ± 4.91 mg/dL (mean \pm sd). After truncation, only 178 or 2.07% of the tests that differed by an absolute value of 21–29 mg/dl were rendered 20 mg/dL apart. Most of the rejected values were from the range of 25–29 mg/dL different, skewing the acceptable data significantly towards the 21–22 mg/dL range. Truncation thus does not randomly render acceptable differences between breath tests of 21 to 29 mg/dL and this procedure retains scientific relevance and does not unfairly prejudice drinking drivers. These results reveal that properly trained qualified breath technicians operate the Intoxilyzer® 5000C with a high degree of precision, resulting in 97% of all paired subject tests being within 20 mg/dL of each other using the untruncated values.

RÉSUMÉ

Dans le cadre d'une étude rétrospective, la précision entre les paires de résultats tronqués et non tronqués a été analysée et comparée en examinant les résultats obtenus avec l'Intoxilyzer® 5000C par les techniciens qualifiés du Service de police de Toronto sur une période de quatre ans s'étalant de 1995 à 1998. Au total 8585 tests ont été analysés. L'écart entre les résultats non tronqués s'est révélé inférieur ou égal à 20 mg/100 mL dans 8309 (97 %) tests, alors qu'un écart se situant entre 21 et 29 mg/100 mL a été observé dans 276 (3 %) des tests. La différence moyenne (en valeur absolue) entre les tests non tronqués dont l'écart était inférieur ou égal à 20 mg/100 mL a été de 7.05 ± 4.9 mg/100 mL (moyenne \pm écart type). Lorsque les résultats étaient tronqués, seulement 178 (2.07 %) des tests dont l'écart se situait entre 21 et 29 mg/100 mL se sont retrouvés en deçà de la valeur limite de 20 mg/100mL. L'écart entre la plupart des valeurs rejetées se situait entre 25 et 29 mg/100 mL, alors que l'écart entre la plupart des valeurs reconnues acceptables se situait entre 21 – 22 mg/100 mL. Les tests dont l'écart se situe entre 21 et 29 mg/100 mL ne deviennent donc pas acceptables de façon aléatoire lorsqu'ils sont tronqués ; la procédure de tronquer les résultats conserve sa pertinence scientifique

- 1 An initial analysis of a more restricted data set of Toronto Police Service Intoxilyzer data was presented at the 47th Annual Meeting of the Canadian Society of Forensic Science, Ottawa, ON, November 1-4, 2000.
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et ne cause pas de préjudice défavorable aux conducteurs en état d'ébriété. Ces résultats révèlent que les techniciens qualifiés adéquatement formés utilisent correctement l'Intoxilyzer® 5000C et obtiennent une bonne précision, de sorte que 97 % de toutes les paires des résultats des tests effectués sur les sujets se situent à l'intérieur de l'écart de 20 mg/100 mL des valeurs non tronquées.

INTRODUCTION

Normally, duplicate breath alcohol samples are obtained from drinking drivers in Canada. For many years, truncated breath results differing by no more than 20 mg/dL have been accepted as a reasonable level of precision for determining the blood alcohol concentration (BAC) of accused drinking drivers. A relatively recent court decision in Ontario determined that untruncated results can, and therefore should, be obtained that differ by no more than 20 mg/dL. Currently, this decision affects only a few counties/regions of the province of Ontario, but is being argued in courts more widely and thus is worthy of scientific scrutiny.

The degree of precision required for approved breath-alcohol testing instruments, such as the Intoxilyzer® 5000C, in Canada is not explained in the Criminal Code. However, the Recommendations of the Alcohol Test Committee of the Canadian Society of Forensic Science (1), the principal scientific advisor to the Minister of Justice for Canada on matters relating to breath and blood alcohol testing, indicate that if two truncated tests are within 20 milligrams in 100 millilitres of blood (the units used in Canada; equivalent to 0.020 g/dL and stated hereafter as mg/dL), they should be regarded as being in good agreement, and used as evidence in court. If the truncated results are greater than 20 mg/dL apart a third test should be performed.

Truncation, rounding unit values of 1-9 down to zero, has long been accepted as a valid means of eliminating the estimation of the "third" digit in breath testing instruments (2) displaying the results in g/dL as 0.000, particularly for those instruments such as the Breathalyzer in which the pointer scale has graduations only for 0.00 and the final (third) digit must be estimated based on whether the pointer is closer to, for example, 0.01, 0.02 or the middle, 0.015. Instruments, such as the Intoxilyzer® 5000C have a screen display and printer output that provides results in g/dL with all three digits. While automatic truncation is available on Intoxilyzer® models, this is not used in Ontario. The continued use of truncation for the results of breath tests obtained by the Intoxilyzer® 5000C was advocated by the Alcohol Test Committee and implemented by the Centre of Forensic Sciences Breath Testing Program, the body that is responsible for training and scientific aspects of breath testing in Ontario. This is reasonable since the variability of any breath test due to the instrument lies within the "third digit" (3) and thus a truncated value will still lie within that range of variability and represents a conservative estimation.

Truncation, however, does lead to a paradox wherein some test results that differ by as much as 29 mg/dL untruncated (e.g. 100 mg/dL and 129 mg/dL) differ by only 20 mg/dL when truncated, while other instances of differences greater than 20 mg/dL (e.g. 99 mg/dL and 120 mg/dL) remain greater than 20 mg/dL apart after truncation. In 1998, a lower court in Ontario agreed with the 20 mg/dL precision between tests, but only for untruncated results if they were obtained with the Intoxilyzer® 5000C (4). This has led to differing standards within the province whereby breath technicians in the jurisdiction of the court above must obtain two suitable breath samples that differ by no more than 20 mg/dL in absolute (untruncated) value, whereas breath technicians in the rest of the province need only follow the original precision of agreement within 20 mg/dL truncated.

This dichotomy of test results leads to several scientific questions. How often does truncation lead to the acceptance of breath tests that differ by 21 to 29 mg/dL? Is the distribution of tests within this group uniform or skewed towards 21 or 29 mg/dL? Is the requirement to obtain untruncated results differing by no more than 20 mg/dL a significant burden, such that the level of precision needs to be decreased? Is truncation reasonable and scientifically valid for reporting results?

One of us (JP) is, and has been, responsible for the breath testing program of the Toronto Police Service (TPS) since the introduction of the Intoxilyzer[®] 5000C late in 1994 (the first police service to use this instrument in Canada). Records of all TPS breath tests are periodically downloaded and stored for future reference and a quality control program. Data for the years 1995 to 1998 includes the introductory period for this instrument and the first Intoxilyzer[®] 5000C breath technicians in Ontario. All were trained to obtain two suitable samples that differ by no more than 20 mg/dL truncated. They thus represent an ideal pool to determine any apparent difficulties that would be imposed by a requirement not to truncate.

MATERIALS AND METHODS

In Ontario, the order of operations for each breath test performed on an Intoxilyzer[®] 5000C is: air blank, 10 systems checks and a check of the three internal electronic standards, calibration check using an external alcohol standard that at 34°C has a target value of 100 mg/dL, air blank, a second series of 10 systems checks and a check of the three electronic internal standards, the subject test (the instrument provides a time period of 5 minutes in which to obtain a suitable sample), and a final air blank. There is a statutory waiting period of at least 15 minutes between the first and second subject tests in Canada (the Intoxilyzer[®] 5000C is programmed to wait 17 minutes before allowing the second subject test). Upon completion of the second breath test, qualified breath technicians are normally instructed to proceed as follows. If the two tests are within 20 mg/dL **truncated**, they can be considered in good agreement and are a reliable representation of the subject's BAC at the time of the tests. If, however, the results differ by more than 20 mg/dL **truncated**, the breath technicians are instructed to complete a third (and possibly further) breath tests until they are satisfied that they have the results of two suitable samples of breath that differ by no more than 20 mg/dL **truncated**. The reasons for, and implications of, requiring more than 3 tests in some instances lies outside of the scope of this paper and will not be discussed.

The Intoxilyzer[®] 5000 series has sufficient memory to hold the results of 50 paired breath tests. The data for each breath test that was available for this study included: the serial number of the instrument used, last name of the subject, date of the occurrence, year, time of the offense, result and time of the first breath test, result and time of the second breath test, and results of the calibration checks performed prior to breath tests one and two. The data relating specifically to the offence (last name of the subject, date of the occurrence, and time of the offense) were used only to identify peculiar tests or results. For this study, we focused on the subject and calibration (Cal. Ck.) test results of all breath tests carried out by Toronto Police Services (formerly Metropolitan Toronto Police) from 1995 to 1998. From a total of 10,433 records, 8,585 (82%) contained two subject tests and were selected for analysis. The rest represent third tests, or incomplete tests (e.g. refusal to perform a second test which results in criminal charge in Canada).

The data were scrutinized for the number of tests that were within 20 mg/dL of each other truncated, versus untruncated. The truncated value with an absolute difference of 21-29 mg/dL data were then analysed for any effects of BAC and whether there was any trend for the first or second test to be the lowest.

RESULTS

Of the 8,585 tests reviewed, 8,309 (97%) were found to be within 20 mg/dL untruncated, versus 276 (3%), that were within 21 to 29 mg/dL (Figure 1). The mean absolute (unsigned) difference between subject tests that were within 20 mg/dL untruncated for all four years was 7.05 ± 4.91 mg/dL (mean \pm sd). Comparing the mean and standard deviation of the differences between breath tests that were within 20 mg/dL untruncated for each of the years shows they did not change in any meaningful way over this time period (from a low of 6.98 ± 4.74 mg/dL in 1996 to a high of 7.20 ± 4.98 mg/dL in 1997).

Of the 276 paired tests with an absolute difference of 21 to 29 mg/dL (Figure 2), truncation reduced this number to 178 or 2.07% (Figure 3). The data shows a definite bias towards the low end of the range (difference of 21 mg/dL) for the untruncated (skewness = 0.74) and especially the truncated data (skewness = 1.20). A distinct drop in acceptable results occurs between 24 and 25 mg/dL, after truncation and no paired tests with a 29 mg/dL difference would have been 'in good agreement' after truncation, despite the theoretical possibility for this occurrence. Almost 84% of the truncated results that differ in absolute terms by greater than 21 mg/dL are less than 25 mg/dL apart. Truncation resulted in rendering only 29 paired tests with an absolute difference of 25 to 28 mg/dL to be within 20 mg/dL out of 8,585 paired subject tests ($\ll 1\%$).

The procedure for each subject test performed on the Intoxilyzer[®] 5000C includes a check of the calibration at 100 mg/dL, using vapours from an alcohol standard manufactured to contain 1.21 ± 0.03 mg/mL of ethanol and heated in a suitable simulator to $34.0 \pm 0.2^\circ\text{C}$. In Ontario this check occurs prior to each subject test and results from 90 to 110 mg/dL indicate the instrument is properly calibrated and the subject test results are reliable. In order to control for the possibility that variability in the instrument could account for subject tests with differences of between 21 and 29 mg/dL, the calibration checks of the instruments made at the time of these tests were analysed. Mean values (Table 1) for the calibration checks were determined for each series of data based on the differences between the breath tests to see if the variability in calibration values was correlated with increasing differences in subject breath test values. The values obtained were within a very narrow range from 96.8 mg/dL to 99.6 mg/dL and did not differ significantly between any of the data series, indicating the instruments were properly calibrated and provided reliable results at the time of the tests. Moreover, the difference between the mean values obtained for the first calibration check (associated with the first subject test) and the second calibration check (associated with the second breath test) was less than 1 mg/dL for all of the data series from subject tests that differed by 21 mg/dL to 29 mg/dL, indicating that instrument variability was not a factor in these differences. Finally, the mean absolute, unsigned differences between each of the paired calibration checks was determined. Although the breath tests differed by 21 to 29 mg/dL, the mean unsigned differences between the two calibration checks remained between 1.3 and 1.8 mg/dL (Table 1) and showed no discernable pattern of change as the differences of the breath tests increased from 21 to 29 mg/dL.

In order to determine if the subject's blood alcohol concentration (BAC) or the quality of sample affected the precision of breath tests obtained, the data were broken down by BAC range and by determining which of the paired breath tests, if any, was statistically higher. For all of the data collected over the four years, the first test had a mean value of 157 ± 6.2 mg/dL and the second test 151 ± 5.7 mg/dL. Contrast this with an average BAC of the 276 tests with differences of 21–29 mg/dL of 185 ± 6.3 mg/dL for the first test. When this data is broken down into ranges of BAC it is clear that most of the paired tests with a difference of 21–29 mg/dL result from testing individuals with BACs greater than

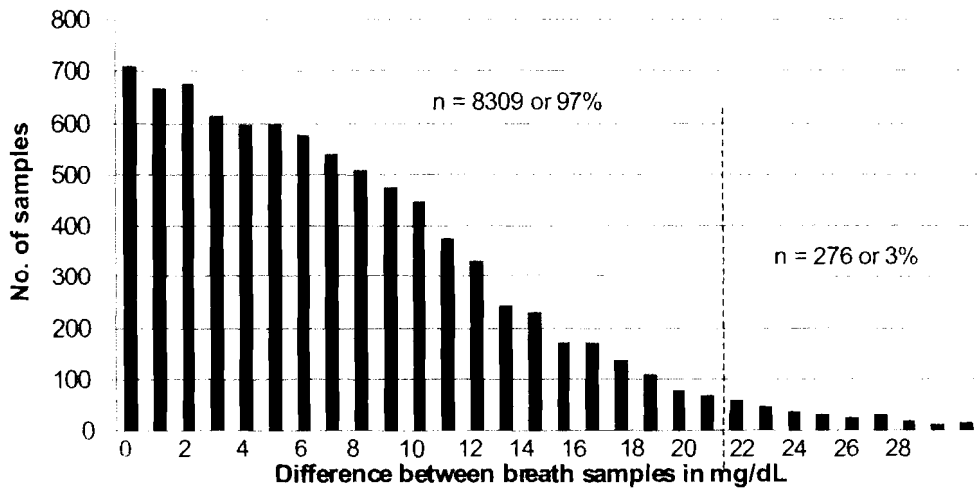


Figure 1. Absolute differences between all paired breath tests with a difference in value between 0 and 29 mg/dL.

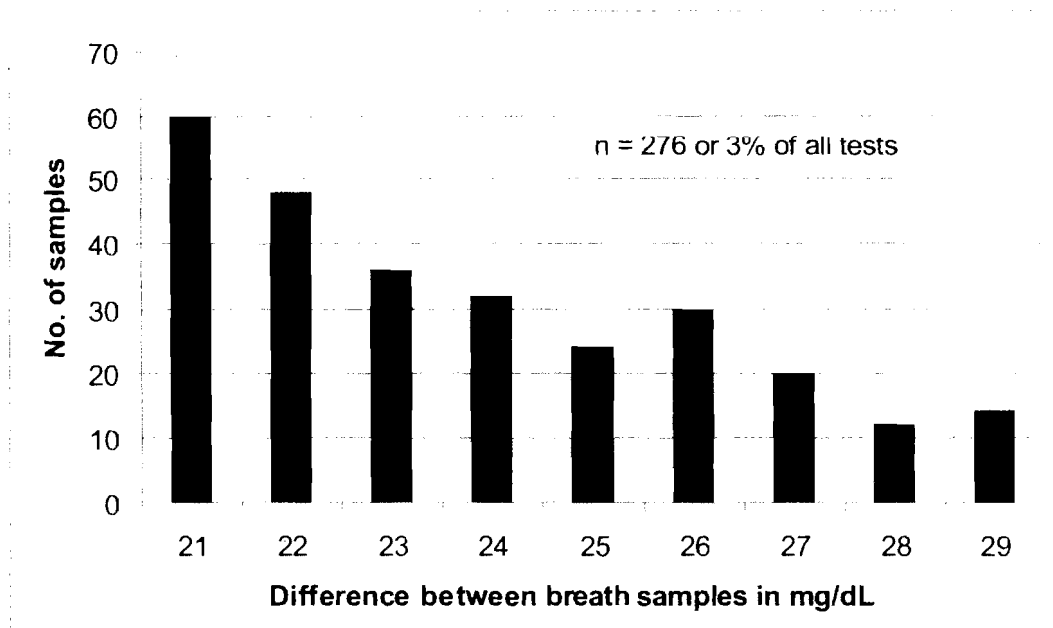


Figure 2. Summary of paired breath tests with an absolute difference of 21 to 29 mg/dL.

150 mg/dL (Figures 3 and 4). Considering which test for each pair produced the lower result, for the 8,585 tests reviewed, 7,146 (83.2%) had a second test with a lower BAC than the first. By comparison, of the 276 tests with an absolute difference of 21–29 mg/dL the second test was lower than the first in almost 94% of the cases (Figure 5; range: 89.5% to 100% of paired results).

TABLE 1.

Mean values (\pm sd.) and the mean unsigned differences (\pm sd.) for the calibration checks (Cal Ck.) performed immediately prior to subject tests with a difference between subject tests from 21 to 29 mg/dL.									
Difference in Subject tests	21 mg/dL	22 mg/dL	23 mg/dL	24 mg/dL	25 mg/dL	26 mg/dL	27 mg/dL	28 mg/dL	29 mg/dL
Cal Ck. 1 mean (mg/dL)	99.65	99.16	98.77	99.09	96.81	98.38	99.16	98.83	99.29
Sd. (mg/dL)	2.9	3.0	3.0	2.2	3.2	2.2	3.2	2.4	3.5
Cal Ck. 2 mean (mg/dL)	99.07	98.45	97.91	98.48	97.27	97.96	98.74	98.64	99
Sd. (mg/dL)	2.9	2.5	2.9	2.2	2.5	2.6	2.4	2.0	3.0
Mean unsigned difference (mg/dL)	1.8	1.8	1.6	1.4	1.8	1.8	1.4	1.3	1.3
Sd. (mg/dL)	1.3	1.4	0.2	1.3	1.7	1.5	1.3	1.4	1.1

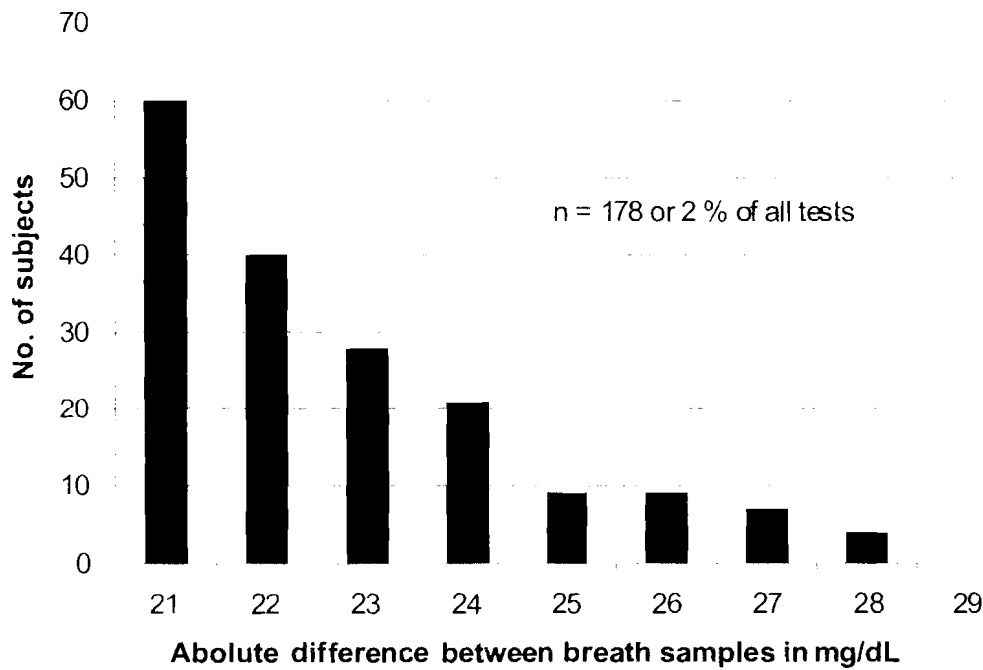


Figure 3. Paired breath tests where the truncated values differ by 20 mg/dL while the untruncated differences ranges from 21 to 29 mg/dL.

Finally, the possibility exists that breath technicians' unfamiliarity and inexperience with the Intoxilyzer[®] 5000C during the first one to two years of the program may have influenced the data and contributed to breath test results with differences between 21–29 mg/dL. As is obvious from Figure 6, the first two years (1995 and 1996) were the source of more paired tests differing by 21 or 22 mg/dL, but higher BAC differences did not vary between years and a similar pattern of decreasing frequency for greater differences in paired tests occurred for each year.

DISCUSSION

These results reveal that properly trained qualified breath technicians operate the Intoxilyzer[®] 5000C with a high degree of precision, resulting in 97% of all subject tests

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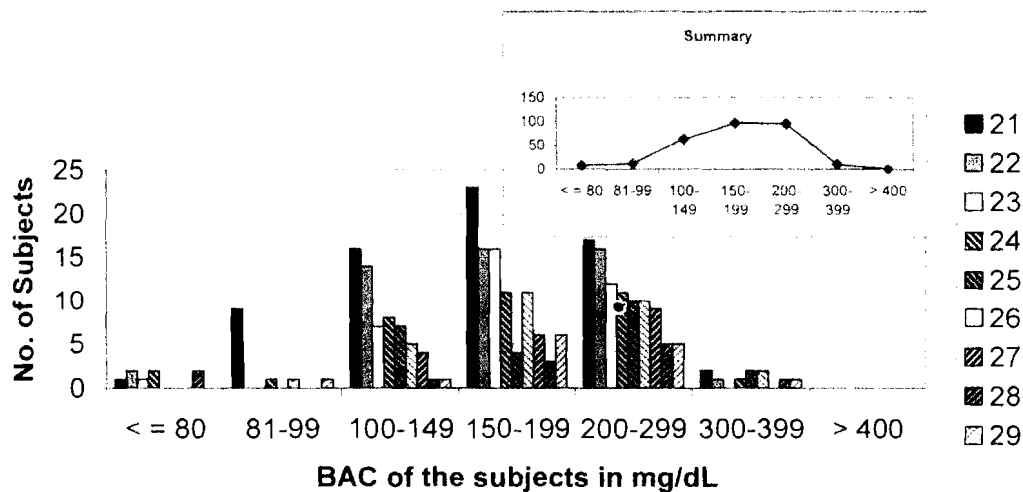


Figure 4. BAC (based on 1st subject test) of the 176 individuals whose breath tests differed in absolute value by 21–29 mg/dL. Inset: Total number of subjects with breath test differences of between 21–29 mg/dL grouped by BAC ranges from < 80 mg/dL to > 400 mg/dL..

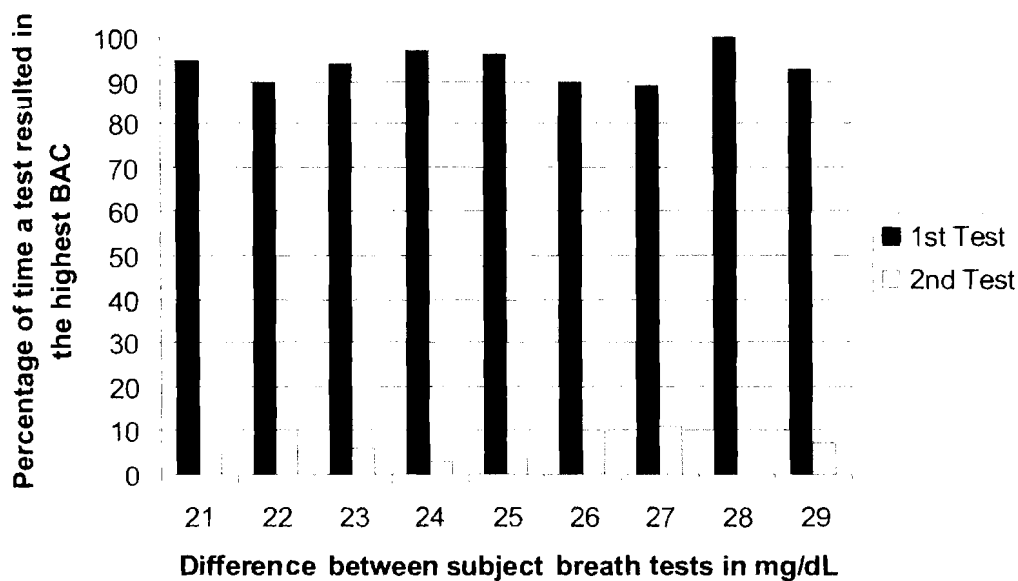


Figure 5. Percentage of time the 1st or 2nd breath test recorded the highest BAC for tests with a difference of 21 to 29 mg/dL.

being within 20 mg/dL untruncated. Following truncation, only 2% of breath tests with absolute differences of 21 to 29 mg/dL were within 20 mg/dL or “good agreement”. Moreover, they demonstrate that, although it is mathematically possible for truncation to lower the difference to 20 mg/dL in breath results with an absolute difference of 29 mg/dL, in fact, breath test results with absolute differences greater than 24 mg/dL not requiring a third test due to truncation are exceedingly rare. Indeed no instances of breath tests

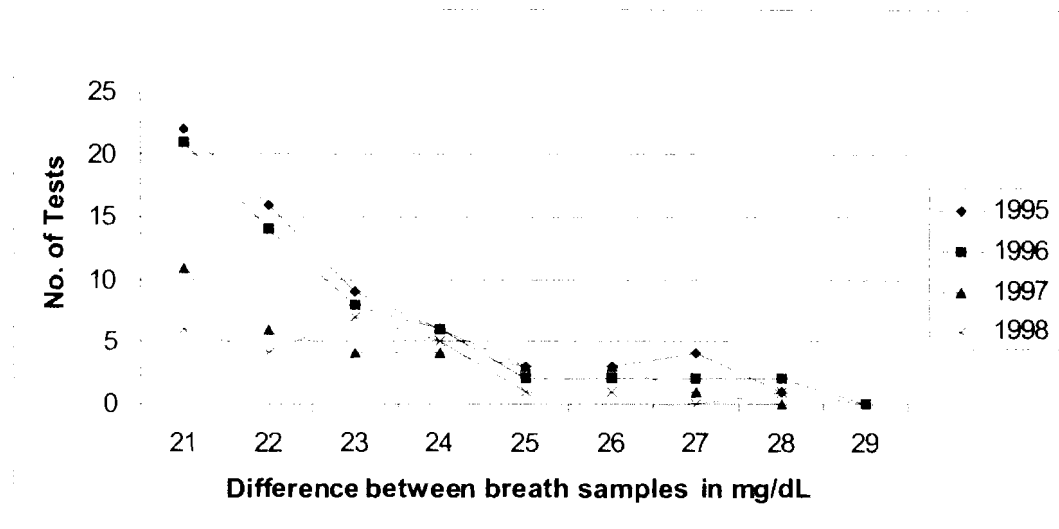


Figure 6. Paired breath tests where the truncated values differ by 20 mg/dL while the untruncated differences ranges from 21 to 29 mg/dL, by the year in which the tests occurred.

29 mg/dL apart were rendered “in good agreement” in four years of breath testing in Canada’s largest city. The heightened skewness of the data following truncation clearly indicates that this practice in fact decreases the acceptance of breath tests with differences greater than 20 mg/dL, especially results that differ by more than 25 mg/dL. Thus, truncation allows for the acceptance of values in a more restricted range (primarily 21–24 mg/dL) than theoretically possible, which dictates that values from 21–29 mg/dL should be randomly made acceptable following truncation.

These findings support the long-held view (1,2) that truncation is a valid method of removing uncertainty or scientific variability from breath results. The results of this retrospective study also demonstrate the precision of breath alcohol testing achieved when the Intoxilyzer® 5000 series instrument is operated by qualified personnel. Indeed, qualified personnel who were required to accept two samples of breath with results that differed by no more than 20 mg/dL in absolute value (i.e. untruncated) would have little difficulty in achieving this target. Qualified breath technicians from the Ottawa Police Service have been meeting these more stringent conditions for approximately the past 7 years due to the decision in *R.v. Mosley* (4) and have had no significant problems⁴.

Gullberg (3) has shown that the “third digit” is randomly distributed from 0–9 when analysing a large number of breath tests (n = 11,480) and argued that truncation provides the most conservative estimate although the chances of the actual value being 0 are equal to that for being 9. It is well known that the greatest variable in alcohol breath testing is the quality of the breath sample obtained (5, 6, 7). We analysed the accuracy and precision of the Intoxilyzer 5000C when it performed calibration checks associated with breath tests having a difference of 21–29 mg/dL. The calibration checks were all accurate to within 1 mg/dL of the target value of 100 mg/dL for the alcohol solution used in Ontario. Further, the paired calibration checks had mean differences of less than 2 mg/dL and did not correlate with the

4. Sgt. Pat Frost, Ottawa Police Service; personal communication.

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observed differences in the breath results. Clearly, the variability in the accuracy and precision of the Intoxilyzer® 5000C is within the value of the “third digit” when analyses of a known alcohol standard are performed, as previously demonstrated by Gullberg (7), and Goldberger and Caplan (8). Thus, the significance of the “third digit” (last digit of the display) of a breath result is diminished by uncertainty due primarily to quality of the sample obtained rather than any specific breath testing instrument’s ability to determine this digit. The continued use of truncation provides a uniform way to handle the uncertainty in the “third digit” due to the quality of the breath samples provided when the qualified breath technician is assessing the precision (the good agreement) of the paired breath samples.

Perhaps not surprisingly, the percentage of tests with an absolute difference of 21–29 mg/dL having a lower second test overwhelmed those with a lower first test (83% versus 17%). These results were primarily from individuals with BACs that were 28 mg/dL higher on average than the whole group of drivers in this study (185 mg/dL versus 157 mg/dL). Reasons for significantly lower second tests range from negative reaction to the results of the first test, increasing somnolence due to the effects of alcohol (quality of sample issues) to the elimination of alcohol over the time period between the two tests. In Canada there is a mandatory minimum waiting period between the two subject tests of at least 15 minutes that, through a subsequent court decision, is extended to 17 minutes (9, 10). Frequently, officers attempt to wait a uniform 20 minutes before performing the second test and a variety of factors can cause additional delays. Even at the lowest rate of elimination of alcohol from the body of 10 mg/dL/h, the BAC of most arrested drivers will drop by slightly more than 3 mg/dL in 20 minutes while an elimination rate of 20 mg/dL/h will result in almost 7 mg/dL eliminated during this waiting period (higher elimination rates would obviously result in more alcohol elimination during this intervening period). Removing this variability with a 2–3 minute period between breath samples could theoretically eliminate a significant number of breath results that differ by more than 20 mg/dL where the second test was lower than the first (83%). A recent investigation by our laboratory (11) into the influence of the elimination of alcohol on creating increased differences between breath results provides evidence that this time period is a causal factor rather than a theoretical consideration in creating differences between two alcohol breath tests obtained from the same individual.

CONCLUSIONS

Properly trained qualified breath technicians operate the Intoxilyzer® 5000C with a high degree of precision, and can obtain two untruncated alcohol breath tests that are no more than 20 mg/dL apart with little difficulty. Nevertheless, the practice of truncation treats differences due to quality of sample in a uniform manner, and provides the most conservative determination of a breath alcohol result. While it does render breath alcohol tests that differ by more than 20 mg/dL acceptable, this occurs very infrequently and primarily from tests that differ by 21–24 mg/dL, not randomly from 21–29 mg/dL as would be expected from a theoretical point of view. Thus, truncation in no way invalidates the scientific acceptability of these results nor does it unfairly prejudice drinking drivers.

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