BRIEF REPORT

THE EFFECT OF DURATION OF BREATH-HOLDING ON EXPIRED AIR CARBON MONOXIDE CONCENTRATION IN CIGARETTE SMOKERS

R.J. WEST

Addiction Research Unit, Institute of Psychiatry, London

Abstract — Exhaled alveolar air contains carbon monoxide that has passed from the blood during a period of breath holding and so provides an accurate guide to carboxyhaemoglobin concentration, itself affected by inhaling tobacco smoke. It has been claimed that breath hold duration makes no appreciable difference to the expired air carbon monoxide (ECO) concentration obtained. A study was conducted to determine the relationship between duration of breath holding prior to exhalation and ECO value. It was found that ECO concentration increased systematically up to 25 seconds of breath holding, with the curve beginning to flatten off after 15 seconds. It is concluded that where possible a breath hold duration of at least 20 seconds should be used and that shorter durations do not provide ECO concentrations comparable with the 20-second value.

Expired air carbon monoxide (ECO) concentration has been shown to provide an accurate indirect measure of carboxyhaemoglobin (COHb) level ($r = .98$) and thus provides a simple breath test for assessing a smoker's levels of intake (Jarvis, Russell, & Saloojee, 1980). It is also used as a means of validating self-reported quitting in smoking intervention studies (Ohlin, Lundh, & Westling, 1976).

The usual method of determining an individual's ECO concentration requires the subject to inhale fully and hold his or her breath for a specified period of time to allow the CO levels in the alveolar air and the blood to equilibrate. It has been argued that 20 seconds should be sufficient for this purpose. The subject then exhales into a bag with some arrangement to discard 200–300ml deadspace enabling the rest to be passed to a measuring instrument such as an Ecolyzer (Jarvis et al., 1980).

The question of how long the subject should hold the breath before exhaling in order to obtain the best estimate of COHb levels has not been satisfactorily determined. The 20-second period was based on a paper by Jones, Ellicott, Cadigan, and Gaensler (1958) which showed that the expired air CO concentration for a given COHb level reached an asymptote at about 20 seconds. However, this was for COHb saturations substantially higher than those found in the average smoker (i.e., greater than 7.8%). On the other side of the coin, it has been claimed that a shorter breath hold or even none at all gives expired air CO concentrations which approximate sufficiently closely to the 20 second values for it to make little or no difference (Henningfield, Stitzer, & Griffiths, 1980).

Expired air carbon monoxide is increasingly used as an objective marker of smoking behaviour and it is important that the method used to obtain the samples should provide data that is both accurate and consistent across studies. The present study sought

Requests for reprints should be sent to R.J. West, Dept. of Psychiatry, Institute of Psychiatry, 101 Denmark Hill, London SE5 8AF England.

to establish whether a 20-second breath holding duration gives an asymptotic ECO reading, and whether shorter breath holding durations give ECO concentrations which approximate closely to the 20-second value.

SUBJECTS, METHODS, AND RESULTS

The subjects were 22 cigarette smokers (13 female and 9 male) with a mean daily consumption of 26.4 cigarettes and a mean age of 38.5 years. A period of at least 5 minutes had elapsed since the last cigarette. A series of ECO measures were taken with an interval between them of about 1 minute. For each measure subjects were asked to breathe out, and then inhale deeply. They were asked after an interval of breath holding to breathe out through a one way valve into a length of anaesthetic tubing. There was a small outlet at the top of the tube through which an Ecolyzer (Series 2000) sucked the air back through a manometer line for analysis. This method ensured that the air from the dead space was discarded and that the end alveolar air was sampled by the Ecolyzer. There were nominally seven different lengths of breath holding: immediate exhalation, 5 secs, 10 secs, 15 secs, 20 secs, 25 secs and 30 secs. Whether or not subjects proceeded through these durations of breath holding upwards or downwards was determined randomly for each subject. One subject was unable to retain the breath for 25 and 30 secs and a further four were unable to hold their breath for 30 secs.

The results showed clear and statistically significant ($p < .01$ by related t test) increases in ECO concentration up to 25 seconds. The values in parts per million for durations of breath holding from 0 to 30 seconds were: 20.2, 24.0, 27.2, 28.8, 30.2, 31.0 and 30.2. The difference between the mean ECO after immediate exhalation and after 20 seconds of breath holding was 10 ppm. Linear regressions were calculated between the 20-second concentrations and the others. The correlations of the 0, 5, 10, 15, 25 and 30 second values with the 20 second value were: .913, .986, .991, .996, .999 and .993 respectively. It is clear that breath holds of 5 seconds or more gave results which correlated almost perfectly with the 20-second results.

DISCUSSION

The asymptotic expired air carbon monoxide concentration was reached some time after 20 seconds of breath holding but before 30 seconds. The mean value of around 30 ppm at 20 seconds corresponds to a COHb of about 5%, which is close to the mean found in other samples of smokers (cf. Wald, Idle, Boreham, & Bailey, 1980). The fact that the asymptote occurred after 20 seconds suggests that a 20-second breath hold is not necessarily the optimum duration for estimating COHb concentrations. However, the correlation between the 20-second value and the 25- and 30-second values is so close to unity that the scope for improvement must be marginal. Of greater significance is the fact that shorter breath holding durations gave substantially lower ECO values, so that it would not be reasonable to substitute, say, an immediate exhalation or a 5-second breath hold for the 20-second duration. On the other hand, the shorter breath hold durations did give values which correlated very well with the 20-second value (which has been validated against COHb). Therefore, if a consistent duration were used throughout a given study and the researcher were only interested in comparisons within that sample, it would be feasible to use a breath hold duration of less than 20 seconds. It must be noted, however, that with breath holding durations of less than 15 seconds, small differences in timing make a substantial difference so that greater care would need to be taken to ensure the accuracy with which the interval is timed.

REFERENCES

Jarvis, M.J., Russell, M.A.H., & Saloojee, Y. Expired air carbon monoxide: a simple breath test of tobacco smoke intake. *British Medical Journal,* 1980, **281,** 484–485.

Jones, A.H., Ellicott, M.F., Cadigan, J.B., & Gaensler, E.A. Relationship between alveolar and blood carbon monoxide concentrations during breathholding. *Journal of Laboratory and Clinical Medicine,* 1958, **51,** 553–665.

Henningfield, J.E., Stitzer, M.L., & Griffiths, R.R. Expired air carbon monoxide accumulation elimination as a function of number of cigarettes smoked. *Addictive Behaviors,* 1980, **5,** 265–272.

Ohlin, P., Lundh, B., & Westling, H. Carbon monoxide blood levels and reported cessation of smoking. *Psychopharmacology,* 1976, **49,** 263–265.

Wald, N.J., Idle, M., Boreham, J., & Bailey, A. Inhaling habits among smokers of different types of cigarettes. *Thorax,* 1980, **35,** 925–928.