# Breath carbon monoxide as an indication of smoking habit in the military setting

**E C T Low, M C C Ong, M Tan**


## ABSTRACT

**Introduction: The breath carbon monoxide (CO) monitor has been shown to be an effective tool in predicting smoking habits. This study aims to assess whether the breath CO level can be employed to determine a person's smoking habit in the military setting and to analyse various factors that can influence the breath CO levels.**

**Methods: 155 navy personnel were questioned on their smoking habits in phase one of the study. The subjects were explained the objective of the study and instructed to provide two breaths into the CO monitor (EC-50 Smokerlyser, Bedford Instruments, Kent, UK). In a subsequent single-blind study, 40 trainees were not told of the purpose of the study and were assessed via a questionnaire and smokerlyser estimation. Descriptive statistics were used to examine the data and assess distribution. Depending on the distribution, a two-sample t test or Mann-Whitney U test were used to test for a significant difference between CO levels among smokers and non-smokers.**

**Results: In phase one, the mean breath CO levels were 11.6 (± 6.2) ppm for smokers and (1.9 ± 0.9) ppm for non-smokers (p-value less than 0.0001). A cut-off level of 5 ppm gave a sensitivity of 96 percent and a specificity of 98 percent. The high CO levels were clustered within five hours of the last cigarette smoked. Therefore, this value may not reliably predict smoking habits if an individual smoked more than five hours before the test. Of the 40 subjects in phase two, five smokers who stated that their last cigarette smoked was 48 hours before the breath test had a mean CO level greater than 5 ppm. (range of 5.5 to 18.0 ppm). On further questioning, all admitted to having smoked on the day of the test.**

**Conclusion: The breath CO monitor has good potential for use as an adjunct in future smoking control assessments and a reading greater than 5 ppm strongly suggests that the military outpatient is a smoker.**


**Keywords: breath carbon monoxide, carbon monoxide, military, smoking, smoking control**

*Singapore Med J 2004 Vol 45(12):578-582*

## INTRODUCTION

The Singapore Armed Forces conduct an annual smoking assessment as part of the healthy lifestyle competition. Using self-reporting via a questionnaire, this method has been shown to be unreliable as many smokers deny their habit, thus making counselling impossible[1]. Cigarette smoke contains many different chemicals, which are inhaled through the respiratory system, absorbed into the circulatory system, and distributed to various organ systems where detrimental effects may occur. Many specific biochemical markers are available for smoking habit assessment, but most of them are expensive to perform and may be invasive. Nicotine, cotinine or thiocyanate levels in the plasma or urine may be used to indicate smoking status[2], but blood tests are invasive and neither the blood nor the urine test provide an immediate assessment. Breath carbon monoxide (CO) measurement, on the other hand, has been shown in several studies to be an effective and easy tool for smoking assessment, as it correlates well with blood carboxyhaemoglobin (COHb)[3].

Jarvis et al[2] concluded that CO measured as blood COHb or in expired air gave a sensitivity and specificity of about 90%. They suggested that for most clinical applications, CO provides an acceptable degree of discrimination and is considerably cheaper and simpler to apply. Another study[4] compared the different tests, namely: serum thiocyanate, urine cotinin, and CO in expired air. The results indicated that the sensitivity and specificity of expired air CO were 98% and 100%, respectively. This compared favourably to serum thiocyanate with results of 93% and 82%, respectively, as well as cotinine in the urine with results of 97% and 83%, respectively. Hence, the

**Naval Medicine and Hyperbaric Centre**
**AFPN, Sembawang Camp**
**36, Admiralty Road West**
**Singapore 759960**

E C T Low, MPH, FRCA, FAMS
Chief Naval Medical Officer

M C C Ong, MBBS, MMed, DMA
Head

**National Health Care Group**

M Tan, MBBS, DFD
Medical Officer

**Correspondence to:**
Dr Mark Tan
72 Hougang Avenue 7
#07-12, The Florida
Singapore 538805
Tel: (65) 6315 6834
Fax: (65) 6315 6834
Email: minglong@cyberway.com.sg

conclusion was that CO levels were sufficient for validating smoking status.

Following inhalation, CO from cigarette smoke displaces oxygen in the erythrocyte to form COHb. In this form, CO has a half-life of about five to six hours[5,6] and may remain in the blood for up to 24 hours, depending on factors such as gender, physical activity and ventilation rate[7]. While some exposure to CO may occur in daily life due to environmental pollution, passive smoking and occupational exposure, the most likely cause of high exposure is occult CO smoking[8]. This study aims to determine whether a portable CO monitor can be used to assess breath CO level and to reliably determine smoking habit in the military setting, by comparing the breath CO levels in smokers and non-smokers, and to assess various factors which may influence breath CO levels.

## METHODS

The EC-50 Smokerlyser (Bedfont Instruments, Kent, UK) is a reliable, portable breath CO monitor, and has previously been shown to be effective[3,9]. This device was used to measure CO levels. It converts CO to carbon dioxide ($CO_2$) over a catalytically- active electrode. On breath-holding, the CO in the blood forms an equilibrium with the CO in the alveolar air, resulting in a high degree of correlation between breath CO levels and COHb concentration. This enables the Smokerlyser to accurately estimate the blood COHb concentration from the breath CO level. The Smokerlyser was calibrated using a mixture of 50 ppm CO in air. To take the breath test, all subjects were asked to exhale completely, inhale fully and breath-hold for 15 seconds. If they were unable to hold their breath for 15 seconds, they were asked to hold it for long as possible and the length of time was recorded. They then exhaled slowly and fully into the mouthpiece of the instrument, in order to sample the alveolar air. The highest CO reading was then recorded.

The study was conducted in two phases. Phase one was conducted in November 2001. Navy personnel were randomly picked without being forewarned about the study. Hence, they did not have the opportunity to refrain from smoking on the day of the study. The subjects were briefed on the intention of the study and assured confidentiality. This was to encourage accurate reporting of smoking habits. Each subject was asked to provide two breaths for testing, since a previous study had reported that the second reading was significantly higher than the first[9]. Background information on general health, smoking habits, exercise, and exposure to passive smoking were collected via a questionnaire.

To assess their general health, subjects were asked if they had any current or previous medical problems. Those who had problems were reviewed by the medical officer who, in turn, confirmed the problem reported. For passive smoking, they were questioned if any of their family members or colleagues smoked. They were questioned if they had undergone any form of physical exercise in the last 24 hours and if so, they were asked to provide details as to the type and duration of exercise. It was difficult to quantify both passive smoking and exercise. Smoking habits were assessed based on the duration they had been smoking, number of cigarettes smoked in the last 24 hours, and the last cigarette smoked during the last 24 hours.

Phase two of the study was conducted at the same time as phase one. The subjects were assessed in the same way, but were not informed of the purpose of the study or what the equipment measures. Similar background information on the subjects was obtained. Data from phase one of the study was used as a guide to compare their smoking habit claims with the breath CO level measured. If there was any discrepancy, the implication of the study was explained to them and their smoking status re-confirmed. All results were analysed using SPSS for Windows version 10.0 (SPSS Inc, Chicago, Illinois, USA). Descriptive statistics were used to examine data and assess distribution. Depending on the distribution, a two-sample t test or Mann-Whitney U test was used to test for a significant difference in CO levels between smokers and non-smokers.

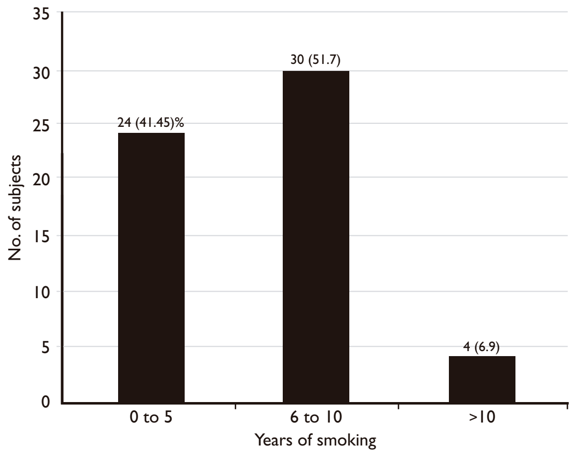
## RESULTS

A total of 155 subjects participated in phase one. 95% of the study subjects were males, and 5% were females. All were able to breath-hold for 15 seconds. There was no significant difference between the first and second breath CO levels. The mean age of the participants was 21.1 years, with age range of 19 to 25 years old. In terms of smoking status, 57% were non-smokers, 37% were smokers and 6% were ex-smokers. The information on duration of smoking habits among those declared smokers were collected (Fig. 1). The biggest group was found among those who smoked between six and 10 years. The mean number of cigarette smoked in the past 24 hours was 11.5. 60% had smoked ≤10 sticks in the 24 hours preceding the breath test.

The mean CO levels in non-smokers and smokers were 1.9 ppm and 11.6 ppm, respectively. The difference was very significant, with a p-value $<0.001$. All had reported smoking within the last 24 hours of the breath test. There was a significant positive correlation between breath CO levels and the number of cigarettes smoked in the past 24 hours, with a positive correlation value of 0.603. High CO levels were clustered within individuals who smoked within the last five hours. A significant negative correlation with the last cigarette smoked was also observed, with a negative correlation value of -0.374. Likewise, a similar clustering of CO levels in individuals who smoked within the last five hours was seen. However, there was no correlation between breath CO levels and passive smoking, physical exercise and upper respiratory tract infection (URTI).

Forty personnel were asked to perform the breath CO test within a single day in phase two. The distribution of smoking status and CO levels are shown in Table I. None of the 13 smokers reported smoking in the last 24 hours before the study, and one had not smoked for the last five days. Interestingly, the majority answered that they had not smoked for 48 hours. In smokers who had not smoked in the last 24 hours, the minimum CO level was 1.5 ppm and the maximum CO level was 18 ppm. Again, the CO level of five smokers in this group was unexpectedly high (Table II). When informed of the implications of their results, they revealed that they had smoked within the last 24 hours. They had concealed their smoking status as they were prohibited from smoking in the last two days. These findings confirmed that breath CO monitoring was a useful adjunct to confirm smoking status compared to just self-reports.

**Fig. 1** Duration of smoking habit.




Bar chart shows the smoking habits of the smokers in the sample population by how long they have smoked.The horizontal axis shows the years they have been smoking and the vertical axis the number of individuals involved.

**Table I. Number of ex-smokers, smokers and non-smokers in phase two of the study and the minimum as well as maximum CO levels obtained in each group.**

| | Ex-smoker | Smoker | Non-smoker |
|---|---|---|---|
| No. of subjects | 6 | 13 | 21 |
| Minimum CO level/ppm | 1 | 1 | 1 |
| Maximum CO level/ppm | 3 | 18 | 3 |

## DISCUSSION

The CO monitor has been shown to be an immediate, non-invasive, simple and effective test of confirming a patient's smoking status[3,10,11]. It works well in the military and public settings, although adjustments must be made in the interpretation of results. Phase one of the study shows that the best cut-off breath CO level for the determination of smoking status was 5 ppm as it gave the best sensitivity and specificity. As there was a clustering of CO levels in individuals who smoked within the last five hours, this cut-off level may be a useful adjunct in detecting smoking status in individuals who have smoked within the last five hours. However, it is lower than the usual 6 to 10 ppm, as recommended by other studies[2,3,6]. Middleton and Morice[3] reported a cut-off level of 6 ppm in 94% of smokers and 96% of non-smokers in a respiratory outpatient clinic. Jarvis et al[2] and Crowley et al[6] demonstrated that a cut-off breath CO level of greater than 8 ppm is strongly associated with self- reports on smoking, while Tonnesen et al[11] and Jorenby et al[12] used 10 ppm as a cut-off.

The low cut-off breath CO level in this study could be due to a higher level of physical activity

**Table II. Subjects who had unexpectedly high breath CO levels despite declaring that they had not smoked for the past 48 hours of subjects and actual timing of last cigarette smoked.**

| Subject | Average breath CO level (ppm) | Declared last cigarette smoked (hours) | Actual last cigarette smoked (hours) |
|---|---|---|---|
| A | 5.5 | 48.0 | 3.0 |
| B | 6.0 | 48.0 | 4.0 |
| C | 8.5 | 48.0 | 2.0 |
| D | 13.0 | 48.0 | 1.0 |
| E | 18.0 | 48.0 | 1.0 |

among smokers in military personnel, as exercise and higher ventilatory rates would lead to increase clearance of CO and hence lower CO levels[13], though the association between physical activity and breath CO levels is not strong. In addition, given certain restrictions in the military setting, our smokers generally do not smoke as much during office hours. The significant correlation between the numbers of cigarettes smoked in the past 24 hours with breath CO levels seen in our study has also been reported in other studies[14]. The other significant correlation was the time of the last cigarette smoked, which could be explained on the basis of the half-life of CO being 5 to 6 hours[5,6]. Terao et al[14] also stated that the time lapsed since last smoke had effects on the expired air carbon monoxide levels.

In our study, URTI had no effect on breath CO levels although some other studies did show that breath CO levels might rise transiently with URTI. Yamaya et al[15] found that exhaled CO concentrations rose to 5.6±0.4 ppm during active URTI, and decreased to 1.0±0.1 ppm during recovery. Hence, high readings in non-smokers with URTI should be interpreted with caution. Viral infection is thought to induce haeme oxygenase in various cells of the upper and lower respiratory tract, resulting in increased CO formation. It is believed that this has an anti-viral effect.

Other studies have found that breath CO levels may be raised in seasonal allergic rhinitis[16] and numerous inflammatory lung diseases, including bronchiectasis, asthma[17] and primary ciliary dyskinesia, where mean values of 7 ppm have been reported. People with active symptomatic allergic rhinitis were found to have higher CO levels[16]. The severity of the asthma and degree of control correlate with CO levels. Treatment decreases the exhaled CO levels. It has been suggested that there is a significant inverse relationship between the exhaled CO concentrations and the forced expiratory volume in one second in all asthmatic patients[17]. Hence, other tests may be required to confirm smoking status if raised CO levels are obtained.

No correlation was found with passive smoking in this study, although other studies have demonstrated increased CO breath levels with passive smoking. Jarvis et at[19] demonstrated that non-smokers exposed to tobacco smoke under natural conditions for two hours in a public house had an increase in expired air CO of 5.9 ppm. However, they cautioned that this form of exposure is relatively high, which happens rarely in everyday living. Any health risks of passive smoking probably depend less on quantitative factors than on qualitative differences, between side-stream and mainstream smoke. Hovell et al[20] concluded that current data show only moderate concordance between environmental tobacco smoke and biological means of measurement of tobacco smoke exposure. They maintained that future studies need to be done to better understand effects of side-stream smoke on the biological markers.

Exercise level was not correlated with breath CO levels. This may be due to difficulties in quantifying and defining of levels of physical activity. There were five people who were not truthful in revealing their smoking status, leading to falsely-elevated breath CO levels. This finding has also been described by Middleton and Morice[3]. Eight individuals who declared themselves as non-smokers were found to have high CO levels, four of whom had readings of greater than 10 ppm. Subsequently, seven individuals were found to be untruthful as they had a financial incentive to conceal their habit and one individual was in doubt over his true smoking status. The authors therefore recommended other confirmatory tests.

In conclusion, the EC-50 Smokerlyser is a quick, simple and inexpensive adjunct to predict the smoking status of military personnel in Singapore. It may also help to predict smoking status in annual smoking surveys and should be combined with other methods. A breath CO level greater than 5 ppm may be more appropriate in the military setting. The value of the CO breath lies in its ability to demonstrate immediately the adverse effects of smoking. However, CO levels are only transient readings and may not communicate the long- term effects of smoking to smokers.


## ACKNOWLEDGEMENTS

We thank Dr Kelvin Thia, former Head of the Diving Medicine Branch of the Naval Medicine and Hyperbaric Centre, who is currently a National Health Care Group Medical Officer, for the help with the EC-50, and personnel from the Naval Medicine and Hyperbaric Centre for assistance in data collection.


## REFERENCES


1. Daly RJ, Blann AD. Self-reported smoking in vascular disease: the need for biochemical confirmation. Br J Biomed Sci 1996; 53:204-8.
2. Jarvis MJ, Tunstall-Pedoe H, Feyerabend C, Vessey C, Saloojee Yl. Comparison of tests used to distinguish smokers from non-smokers. Am J Public Health 1987; 77:1435-8.
3. Middleton ET, Morice AH. Breath carbon monoxide as indication of smoking habit. Chest 2000; 117:758-63.
4. Waage H, Silasand T, Urdal P, Langard S. Discrimination of smoking status by thiocyanate and cotinine in serum, and carbon monoxide in expired air. Int J Epidemiol 1992; 2:488-93.
5. Peterson JE, Stewart RD. Absorption and elimination of carbon monoxide by inactive young men. Arch Environ Health 1970; 21:165-71.
6. Crowley TJ, Andrews AE, Cheney J, Zerbe G, Petty J L. Carbon monoxide assessment of smoking in chronic obstructive pulmonary disease. Addict Behav 1989; 14:493-502.

7. Deller A, Stenz R, Forstner K, Konrad F. The elimination of carboxyhemoglobin: gender-specific and circadian effects [German]. Infusionsther Transfusionsmed 1992; 19:121-6.
8. Jarvis M J, Tunstall-Pedoe H, Feyerabend C, Vesey C, Salloajee Y. Biochemical markers of smoke absorption and self-reported exposure to passive smoking. J Epidemiol Community Health 1984; 38:335-9.
9. Jarvis MJ, Belcher M, Vesey C, Hutchison DC. Low cost carbon monoxide monitors in smoking assessment. Thorax 1986; 41:886-7.
10. Wald NJ, Idle M, Boreham J,Bailey A. Carbon monoxide in breath in relation to smoking and carboxyhaemoglobin levels. Thorax 1981; 36:366-9.
11. Tonnesen P, Norregaard J., Mikkelsen K, Jorgensen S, Nilsson F. A double-blind trial of a nicotine inhaler for smoking cessation. JAMA 1993; 269:1268-71.
12. Jorenby DE, Smith SS. Fiore MC, Hurt RD, Offord KP, Croghan IT, et al. Varying nicotine patch dose and type of smoking cessation counseling. JAMA 1995; 274:1347-52.
13. Cope KA, Watson MT, Foster WM, Sehnert SS, Risby TH. Effects of ventilation on the collection of exhaled breath in humans. J Appl Physiol 96:1371-9.
14. Terao A, Konishi M, Baba S, Mannami T. Exposure to tobacco smoke in a Japanese urban population. An analysis using biochemical markers of smoking [Japanese]. Nippon Koshu Eisei Zasshi 1998; 45:3-14.
15. Yamaya M, Sekizawa K, Ishizuka S, Monma M, Mizuta K, Susakai H. Increased carbon monoxide in exhaled air of subjects with upper respiratory tract infections. Am J Respir Crit Care Med 1998; 158:311-4.
16. Monma M, Yamaya M, Sekizawa K, Ikeda K Suzuki N, Kikuchi T. Increased carbon monoxide in exhaled air of patients with seasonal allergic rhinitis. Clin Exp Allergy 1999; 29:1537-41.
17. Zayasu K, Sekizawa K, Okinaga S, Yamaya M, Ohrui T, Sasaki H. Increased carbon monoxide in exhaled air of asthmatic patients. Am J Respir Crit Care Med 1997; 156:1140-3.
18. Ece A, Gurkan F, Haspolat K, Derman O, Kirbas G. Passive smoking and expired carbon monoxide concentrations in healthy and asthmatic children. Allergol Immunopathol (Madr) 2000; 28:255-60.
19. Jarvis MJ, Russell MA, Feyerabend C. Absorption of nicotine and carbon monoxide from passive smoking under natural conditions of exposure. Thorax 1983; 38:829-33.
20. Hovell MF, Zakarian JM, Waklgren DR, Matt GE, Emmons KM. Reported measures of environmental tobacco smoke exposure: trials and tribulations. Tob Control 2000; 9:22-8.