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Should the threshold for expired-air carbon monoxide concentration as a means of verifying self-reported smoking abstinence be reduced in clinical treatment programmes? Evidence from a Malaysian smokers' clinic

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ABSTRACT

Background: It has been proposed that the expired-air carbon monoxide (CO) threshold for confirming smoking abstinence in clinical practice be reduced below 10 ppm. Optimal thresholds may vary across regions. Data are needed to assess the impact of such a change on claimed success.
Methods: A total of 253 smokers who attended the Tanglin quit smoking clinic in Malaysia were followed-up 1, 3 and 6 months after the target quit date. All participants received a standard behavioural support programme and were prescribed either varenicline or nicotine replacement therapy. Expired-air CO was measured at every visit. Respondents' smoking status was assessed using a range of different CO thresholds (3, 5 and 10 ppm) and the impact on quit rates was calculated. Predictors of success as defined using the different thresholds were assessed.
Results: The 6-month abstinence rates were: 1 month — 54.9% at 10 ppm, 54.9% at 5 ppm and 48.6% at 3 ppm; 3 months — 36.0% at 10 ppm, 35.2% at 5 ppm and 30.4% at 3 ppm; 6 months — 24.1% at 10 ppm, 24.1% at 5 ppm and 20.6% at 3 ppm. Older smokers were more likely to be recorded as abstinent at 6 months regardless of the threshold used.
Conclusions: Reducing the threshold for expired-air carbon monoxide concentrations to verify claimed smoking abstinence from 10 ppm to 5 ppm makes minimal difference to documented success rates in Malaysian smoker's clinic patients. Reducing to 3 ppm decreases success rates slightly. Predictors of success at stopping appear to be unaffected by the threshold used.

1. Introduction

Despite the health hazards, 23.1% of Malaysian adults aged 15 years or older smoke tobacco (43.6% of men and 1.0% of women) (National Institute of Health Malaysia, 2011; Global Adult Tobacco Survey, 2011). Almost half (48.6%) of adult smokers report that they have tried to quit smoking but only 9.5% of ever smokers have managed to do so (Global Adult Tobacco Survey, 2011). Smokers' clinics, providing behavioural support plus stop-smoking medication such as nicotine replacement therapy, can dramatically improve rates of success at quitting (Cahill, Stevens, Perera, & Lancaster, 2013) and such services are now available in many countries (Raw, Regan, Rigotti, & McNeill, 2009). Many of them rely on expired-air carbon monoxide (CO) monitoring to verify self-reported abstinence. There has been debate about what is the optimum threshold for this (Al-Sheyab, Kheirallah, Mangnall, & Gallagher, 2015; Cropsey et al., 2014). This paper reports a study that aimed to address this issue.

The measurement of smokers' CO levels provides objective assessment of recent smoking (Sandberg, Skold, Grunewald, Eklung, & Wheelock, 2011; Society for Research on Nicotine & Tobacco, 2002). A threshold of 10 ppm is commonly used in clinical studies (Jorenby et al., 1995; Tonnesen, Nørregaard, Mikkelsen, Jorgensen, & Nilsson, 1993). Other studies have used values ranging from 5 to 8 ppm as the cut-off (Jarvis, Tunstall-Pedoe, Feyerabend, Vessey, & Salojee, 1987; Morabia, Bernstein, Curtin, & Berode, 2001; Joumard, Chiron, Vidon, Maurin, & Rouzioux, 1981; Kapusta et al., 2010; Low, Ong, & Tan,

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Table 1
Socio-demographics, smoking history & current smoking habits.

Characteristics (N = 253)	n (%)
Age (years), mean (SD)	37.9 (11.9)
14–24	23 (9.1)
25–34	92 (36.4)
35–44	61 (24.1)
45–54	55 (21.7)
≥55	22 (8.7)
Gender	
Male	246 (97.2)
Ethnicity	
Malay	197 (77.9)
Chinese	28 (11.1)
Indian	16 (6.3)
Others	12 (4.7)
Education level	
Degree/Masters/PhD	56 (22.1)
Certificate/Diploma/Form 6	56 (22.1)
Upper secondary	108 (42.7)
Lower secondary	26 (10.3)
Primary	7 (2.8)
Occupation	
Professional, technical and business	107 (42.3)
Clerical, service and armed forces	71 (28.1)
Manual	43 (17.0)
Retired, unemployed, housewife or student	32 (12.7)
Chronic diseases	
Hypertension	35 (13.8)
Diabetes	23 (9.1)
Coronary heart disease	5 (2.0)
Lung disease	5 (2.0)
Cancer	1 (0.4)
Others	10 (4.0)
None	186 (80.5)
Age started smoking[a] (yr), median (IQR)	17 (15–20)
Duration of smoking[a] (yr), median (IQR)	19 (12–27)
Average number of cigarettes smoked per day[a], median (IQR)	20 (10–20)
Previous quit attempts[a], median (IQR)	2 (1–4)
Baseline CO reading[a] (ppm), median (IQR)	7 (3–0)
0	14 (5.5)
1–6	107 (42.3)
7–10	72 (28.5)
11–20	50 (19.8)
>20	7 (2.8)
Missing	3 (1.2)

yr = years; ppm = parts per million; SD = standard deviation; IQR = interquartile range. Percentages may not total to 100% due to rounding.
[a] Skewed.

2004; Middleton & Morice, 2000; Sandberg et al., 2011). Getting the right threshold is important because it could undermine motivation for a non-smoker to have his or claim of abstinence incorrectly queried and fail to detect those who have smoked so that remedial action can be taken. In addition, it is crucial for performance monitoring and clinical studies comparing success rates with different treatment options.

Expired air CO has important limitations as a tool for verifying abstinence. The half-life of CO in the blood is around 2 to 4.5 h (Sandberg et al., 2011; Society for Research on Nicotine & Tobacco, 2002) so it cannot detect smoking on the previous day. It also lacks specificity in areas of high pollution from burning fossil fuels, where ambient CO can produce readings as high as 10 ppm and occasionally higher. It also lacks sensitivity to be able to detect very light smoking. The original threshold of 10 ppm was set at a time and under conditions where ambient CO was relatively high. Several researchers have proposed that under most current conditions thresholds of between 8 and 10 ppm are too high (Cropsey et al., 2014; Jarvis et al., 1987; Middleton & Morice, 2000; Morabia et al., 2001). They may incorrectly categorise as abstinent people who have in fact smoked, albeit at a low level (Perkins, Karelitz, Jao, Gur, & Lerman, 2013).

Thresholds as low as 3–6 ppm have been proposed (Jarvis et al., 1987; Javors, Hatch, & Lamb, 2005; Joumard et al., 1981; Kapusta et al., 2010; Low et al., 2004; Middleton & Morice, 2000; Morabia et al., 2001). Some studies involving population surveys have supported this view (Cropsey et al., 2014; Javors et al., 2005). However, in smokers' clinics, the situation is somewhat different from that obtaining in population surveys. An important question is what happens in routine clinical practice.

In a large study involving the English stop smoking services, Brose, Tombor, Shahab, and West (2013) found that reducing the threshold to 5 ppm made very little difference to recorded abstinence rates after 4 weeks and reducing it below that appeared to increase misclassification rate. This was one study in one country. Given that this is a global issue, it is important to assess how far this generalises. Malaysia has developed a national programme of stop smoking services somewhat similar, though with less coverage, to that found in the UK (Wee, Shahab, Bulgiba, & West, 2011a). However, it is a very different country with a different demographic profile. It therefore provides a potentially useful context to assess the generalizability of the UK findings. A previous study used a threshold of 10 ppm, but it is not known whether different results would have been achieved with different thresholds (Ng & Ann, 2012).

Unfortunately it is not possible to undertake a full sensitivity and specificity analysis using data from routine smokers' clinics because of the high rate of drop-out when people resume smoking. This means that two of the four cells needed for such an analysis (smoking/high CO and smoking/low CO) are subject to too great a degree of bias. Brose et al. (2013) used a different method. They examined, for those smokers who were reporting abstinence, what proportion of them would be classified as smokers under different thresholds. It may be expected that as the threshold is lowered, more would be classified as smokers. However, what they found was that it made very little difference down to a threshold of 5 ppm. Below that figure, the proportion classified as smokers rose markedly. They evaluated how far this was likely to be due to an increase in misclassification by examining whether known predictors of abstinence such as age and social grade predicted abstinence better or worse with the various thresholds. They found that under 5 ppm the known predictors started to become less predictive. They argue that this suggested that under the very low thresholds there was an increase in the misclassification rate.

This study used a similar methodology to that used by Brose et al. (2013) in the Malaysian context. The aim was to assess:

1. At what point does reducing the threshold for CO verification of abstinence lead to a meaningful reduction in verified abstinence rates at 1, 3 and 6 months?
2. Do known predictors of abstinence show better or worse prediction of abstinence defined using different thresholds?

2. Methods

2.1. Design

This was a two year follow-up study where we collected data from 253 smokers who attended the Tanglin quit smoking clinic in the Federal Territory of Kuala Lumpur, Malaysia. The same sample was followed-up at 1-, 3- and 6-months.

Table 2
Abstinence rates at 1, 3 and 6 months following the target quit date as a function of CO threshold.

	10 ppm	5 ppm	3 ppm
1 month	139 (54.9)	139 (54.9)	123 (48.6)
3 months	91 (36.0)	89 (35.2)	77 (30.4)
6 months	61 (24.1)	61 (24.1)	52 (20.6)