DETERMINATION OF SMOKING STATUS AMONG THAI EMPLOYEES BY THE BEST EXHALED CARBON MONOXIDE CUT-OFF LEVEL AND ASSOCIATION WITH ORAL HEALTH CONDITIONS

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Abstract. Measurement of exhaled carbon monoxide (ECO) has been used worldwide to evaluate tobacco smoking but no reports among Thai people. The objectives of this study were to determine the best ECO cut-off level to predict tobacco smoking status, then using the best ECO cut-off level to assess the association between ECO cut-off level and oral health conditions among the same group of study subjects. The study sample comprised a total of 455 Thai industrial employees, aged 19-53 years, working in suburban Bangkok, Thailand during 2009-2010. Each participant was interviewed, had their ECO measured and had an oral cavity examined. We plotted a receiver operating characteristic curve and calculated the sensitivity, specificity, and descriptive statistics. We also conducted bivariate and multivariable logistic regression analyses to determine associations between an evaluated ECO level using a normal cut-off of 4 ppm and oral health conditions. Our results showed an ECO ≥ 4 ppm was suggestive of tobacco smoking, with a sensitivity of 78.5% and a specificity of 86.8%. On multivariate logistic regression analysis, we found significant associations between an ECO level ≥ 4 ppm and the following: heavy tooth debris deposits [adjusted Odds Ratio (aOR)=2.154; 95% confidence interval (95% CI):1.234-4.092), dental calculus with bleeding (aOR=3.22; 95%CI:1.156-8.989) and shallow periodontal pockets (aOR=1.278; 95%CI:1.066-1.534). Our results show a direct association between an ECO level ≥ 4 ppm and conditions that precede periodontitis and an association with periodontitis.

Keywords: exhaled carbon monoxide, oral health conditions, industrial employees

INTRODUCTION

The measurement of exhaled carbon monoxide (ECO) level can provide an immediate assessment of smoking status. It is simple, non-invasive, inexpensive and portable (Jarvis *et al*, 1986; Irving *et al*, 1988). Measurement of the ECO level has been used for people who want to stop smoking (Jarvis *et al*, 1987; Irving *et al*, 1988; Hung *et al*, 2006; Brügger *et al*, 2014). ECO level measurement has been used in dental patients to monitor smoking cessation (Frei *et al*, 2012) it has a good correlation with self-reported smoking (Brügger *et al*, 2014). A number of studies have suggested different cut-off ECO levels to determine smoking status

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(Nakayama *et al*, 1998; Middleton and Morice, 2000; Deveci *et al*, 2004; Low *et al*, 2004; Hung *et al*, 2006), but the best ECO level to determine smoking status among Thai people has rarely been reported (Chatrchaiwiwatana and Ratanasiri, 2008; Chatrchaiwiwatana and Ratanasiri, 2017). The association between ECO level and oral diseases has been evaluated (Barbour *et al*, 1997; Williams *et al*, 2000; Arbes Jr *et al*, 2001; Aligne *et al*, 2003; Yamamoto *et al*, 2005; Nishida *et al*, 2008; Erdemir *et al*, 2010; Tanaka *et al*, 2013) but this has only rarely been reported for Thai people (Chatrchaiwiwatana and Ratanasiri, 2011). The purposes of this study were to evaluate the best cut-off ECO level in predicting tobacco smoking first; then using the ECO cut-off level to assess the association between ECO and oral health conditions among the same group of Thai adults.

MATERIALS AND METHODS

Study population

We conducted a cross sectional analytic study of 455 Thai industrial workers (281 males and 174 females, aged 19-53 years) who volunteered to join the study. All the volunteers worked and lived in one Industrial Estate in Pathum Thani Province, Thailand during 2009-2010. Volunteers who were not able to speak or understand Thai and had respiratory diseases or systemic diseases of any kind were excluded from the study. Altogether 121 smokers and 334 non-smokers participated in the study. A smoker was defined as a person who had smoked at least one cigarette a day for a minimum of one year.

The required numbers of participants for our study was calculated based on the difference between mean ± SD of shallow periodontal pocket in ECO ≥4 ppm group (0.71±1.248) and ECO < 4 ppm group (0.47±1.025), with the alpha error 5% (2-tailed test). Based on the given sample size of 455 volunteers, the statistical power of the study was higher than 88%. Alternatively, if the required sample size was determined based on the difference between proportions of people in ECO ≥4 ppm group having dental calculus with bleeding (96.4%) and not having dental calculus with bleeding (3.6%), with the alpha error 5% (2-tailed test), the given sample size of 455 volunteers gave the statistical power of the study higher than 95%.

After obtaining informed consent, each participant was interviewed about their demographics, lifestyles and health information, such as tobacco smoking and alcohol use. An ECO level was measured in each participant using a portable Micro CO Meter (Micro Medical, Kent, England). Each participant also had an oral examined in a dental chair, using a dental mirror, a no.3 explorer and a World Health Organization (WHO) periodontal probe. All the examinations were conducted using natural light. In our study due to time constraints only a simple examine was performed following WHO criteria (WHO,1997). Prior to the study, the examine was tested for intra-examiner reliability and the results revealed a kappa of >0.80.

Interview

During the interview; participants was asked: their age, gender, education level (no education, lower primary school, upper primary school, lower secondary school, upper secondary school, vocational school and university degree), their monthly income, their religion (Bhuddism or others), their smoking status (types, frequency and duration), their alcohol

use (frequency and duration), number of hours worked per week, sleeping habits and exercise habits.

Exhaled carbon monoxide measurement

The ECO level was measured using a Micro CO Meter (Micro Medical, Kent, England), in the open-air. Participants were asked to exhale completely, inhale completely, and then hold their breath for 15 seconds and then exhaled rapidly into the meter. An ambient CO level was measured each time prior to testing the participant to make sure that during the measurements of ECO of participants, ambient air levels were in the range of 0-2 ppm. The standardized breath-hold time of 15 seconds was assumed to be adequate for equilibrium to take place (Deveci *et al*, 2004).

Oral health examination

An oral examination was applied to every participant at the last step by a well-trained dental examiner. Periodontal status was assessed using the Community Periodontal Index (CPI) (WHO, 1997): 0=healthy gingiva, 1=bleeding gingiva, 2=calculus present, 3=calculus with bleeding present, 4=a shallow periodontal pocket present (4-5 mm), 5=a deep periodontal pocket present (6 mm or more), 9=unable to determine and X=a missing data.

A debris index (DI) (WHO, 1997) was determined using the following categorizations: 0=no debris deposits, 1=mild debris deposits (less than 1/3 of the tooth surface), 2=moderate debris deposits (1/3-2/3 of the tooth surface) and 3=heavy debris deposits (greater than 2/3 of the tooth surface).

The presence of dental caries or previous treatment of them was categorized using the decayed, missing and filled teeth (DMFT) index (WHO, 1997): 0=sound teeth, 1=a decayed tooth, 2=a filled decayed tooth, 3=a filled non-decayed tooth, 4=a missing tooth due to caries, 5=a missing tooth for any reason, 6=a tooth treated with sealant or resin, 7=having a crown or an abutment, 8=having an unerupted tooth, 9=other, and 10=having fractured tooth. Caries treatment was coded (WHO, 1997) as: 0=no treatment, P=caries prevention, 1=one surface with a filling, 2=two or more surfaces with fillings, 3=having a crown, 4=having a veneer, 5=having a history of a root canal, 6=having a history of an extraction, and 7=other as specified.

Quality control of the data

Approximately 10% of the subjects examined each day were re-examined to ensure the reliability of the examination was ≥80%.

The questionnaire used for the study was pilot tested twice and causes of confusion were corrected. The data entered into the computer were double-checked for completeness and correctness before conducting the data analysis.

Statistical analysis

Data analysis was done with SPSS for Windows, version 15.0 (SPSS, Chicago, IL). The receiver operating characteristics (ROC) curve, sensitivity and specificity were calculated to find the best cut-off ECO level to predict tobacco smoking. Descriptive statistics and bivariate analysis were calculated. The Mann-Whitney *U* test and chi-square test were used for non-normally distributed of the data. Multivariate logistic regression analysis was conducted to assess potential associations between the cut-off of ECO level and the ability to predict tobacco smoking and the presence of oral health conditions. A p-value < 0.05 was considered statistically significant.

Table 1
Validity of using various ECO cut-off levels to predict tobacco smoking (*N*=455).

ECO cut-off (ppm)	Sensitivity	Specificity	Sensitivity+Specificity
3	0.810	0.751	1.561
4	0.785	0.868	1.653
5	0.702	0.919	1.621
6	0.612	0.952	1.564
7	0.554	0.970	1.524
8	0.504	0.988	1.492
9	0.446	0.991	1.437

ECO, exhaled carbon monoxide; ppm, parts per million.

Ethical considerations

The research protocol was approved by the Ethics Committee for Human Research at Khon Kaen University, Khon Kaen, Thailand (HE591188).

RESULTS

Four hundred fifty-five industrial employee were included in the study. Table 1 shows the sensitivity and specificity of various ECO cut-off levels to predict tobacco smoking. ECO cut-off level of 4 ppm was chosen since it had the highest combined sensitivity and specificity. By using an ECO level of 4 ppm, the sensitivity and specificity for detecting tobacco smoking were 78.5% and 86.8%, respectively (Table 1).

Among 455 subjects, 61.8% were males. Their mean ± standard deviation (SD) age was 30.0 (± 5.1.) (range : 19.8-53.0) years. Thirty-six percent of subjects had a secondary school education level and 32.6% had a vocational school education. Forty-two point two percent of subjects were from northeastern Thailand. Twenty-six point six percent smoked cigarettes and 52% used alcohol (Table 2).

The mean(±SD) ECO level among all subjects was 3.74 (±5.48) (range: 0-32) ppm; among smokers the mean (±SD) ECO level was 9.53 (7.56)(range: 0-32) ppm; among non-smokers the mean (±SD) ECO level was 1.64(±1.91) (range: 0-11 ppm) (Table 2).

Among our study subjects 69% had untreated caries, 50% had experienced tooth loss, 84.4% had a decayed, missing, or filled tooth, 25.9% had shallow periodontal pockets, 6.8% had deep periodontal pockets, 59.8% had gingival bleeding, 92.7% had calculus with bleeding, 98.0% had mild debris deposits, 57.6% had moderate deposits, and 9.5% had heavy debris deposits, the mean DMFT index was 5.16 (Table 3).

On bivariate analysis an ECO level ≥ 4 ppm was significantly associated with filled teeth both presence of filled teeth and number of filled teeth, the presence of heavy dental debris deposits, gingival bleeding, dental calculus with bleeding and shallow periodontal pockets (Table 4).

On multivariable logistic regression analysis an ECO level ≥ 4 ppm was significantly associated with heavy dental debris deposits, dental calculus with bleeding, and shallow periodontal pockets. People with heavy dental debris deposits, dental

Table 2
Baseline characteristics of study participants (*N*=455).

Characteristics	Value
ECO level, range; mean ± SD in ppm	0-32; 3.74 ± 5.48
ECO level among smokers, range; mean ± SD in ppm	0-32; 9.53 ± 7.56
ECO level among nonsmokers, range; mean ± SD in ppm	0-11; 1.64 ± 1.91
Age, range; mean ± SD in years	19.5-53; 30.01 ± 5.07
Monthly income, range; mean ± SD in Thai baht	4,800-48,000; 10,400 ± 4,264
Body Mass Index, range; mean ± SD	16.42-37.78; 22.02 ± 3.31
Gender, *n* (%)	
Male	281 (61.8)
Female	174 (38.2)
Hometown, *n* (%)	
North	128 (28.3)
East	3 (0.7)
Central	122 (26.9)
West	1 (0.2)
South	8 (1.8)
Northeast	191 (42.2)
Education, *n* (%)	
Upper primary school	8 (1.8)
Lower secondary school	44 (9.7)
Upper secondary school	163 (36.0)
Vocational school	148 (32.6)
University degree or higher	90 (19.7)
Tobacco smoker, *n* (%)	
No	334 (73.4)
Yes	121 (26.6)
Alcohol use, *n* (%)	
No	218 (48.2)
Yes	234 (51.8)

ECO, exhaled carbon monoxide; SD, standard deviation; ppm, parts per million.

calculus with bleeding, and more shallow periodontal pockets were significantly more likely to have an ECO level ≥ 4 ppm and were significantly more likely to be smokers (Table 5).

DISCUSSION

The proportion of smokers in our study (26.6%) was lower than previous studies (Chatrchaiwiwatana, 2003; Chatrchaiwiwatana, 2007; Chatrchaiwiwatana and Ratanasiri, 2008). The mean ECO levels among nonsmokers (1.64 ppm), and among smokers (9.53 ppm) in our study were lower than previous studies (Chatrchaiwiwatana and Ratanasiri, 2008; Chatrchaiwiwatana and Ratanasiri, 2011).

The ECO cut-off of 4 ppm for determining tobacco smoking among our study participants is in agreement with some previous studies (Kauffman *et al*,

Table 3
Oral health characteristics of participants (*N*=455).

Characteristics	Value
Decayed teeth, range; mean ± SD in number	0-15; 2.53 ± 2.88
Missing teeth, range; mean ± SD in number	0-9; 1.18 ± 1.66
Filled teeth, range; mean ± SD in number	0-14; 1.45 ± 2.57
Decayed Missing Filled Teeth, range; mean ± SD in number	0-18; 5.16 ± 4.37
Bleeding gingiva, range; mean ± SD	0-6; 1.58 ± 1.77
Dental calculus, range; mean ± SD	0-3; 0.04 ± 0.26
Dental calculus with bleeding, range; mean ± SD	0-6; 3.64 ± 1.90
Shallow periodontal pockets, range; mean ± SD	0-6; 0.54 ± 1.10
Deep periodontal pockets, range; mean ± SD	0-5; 0.11 ± 0.48
Mild dental debris deposit, range; mean ± SD	0-6; 3.48 ± 1.52
Moderate dental debris deposit, range; mean ± SD	0-5; 1.09 ± 1.20
Heavy dental debris deposit, range; mean ± SD	0-3; 0.13 ± 0.43
Decayed Missing or Filled Teeth, *n* (%)	
No	71 (15.6)
Yes	384 (84.4)
Decayed teeth (untreated dental caries), *n* (%)	
No	141 (31.0)
Yes	314 (69.0)
Missing teeth, *n* (%)	
No	227 (49.9)
Yes	228 (50.1)
Filled teeth, *n* (%)	
No	267 (58.7)
Yes	188 (41.3)
Gingival bleeding, *n* (%)	
No	183 (40.2)
Yes	272 (59.8)
Dental calculus, *n* (%)	
No	445 (97.8)
Yes	10 (2.2)
Dental calculus with bleeding, *n* (%)	
No	33 (7.3)
Yes	422 (92.7)
Shallow periodontal pockets, *n* (%)	
No	337 (74.1)
Yes	118 (25.9)
Deep periodontal pockets, *n* (%)	
No	424 (93.2)
Yes	31 (6.8)
Periodontitis, *n* (%)	
No	332 (73.0)
Yes	123 (27.0)
Mild dental debris deposit, *n* (%)	
No	9 (2.0)
Yes	446 (98.0)
Moderate dental debris deposit, *n* (%)	
No	193 (42.4)
Yes	262 (57.6)
Heavy dental debris deposit, *n* (%)	
No	412 (90.5)
Yes	43 (9.5)

SD, standard deviation.

Table 4
Association between an ECO level> 4 ppm and oral health conditions (N=455).

Oral health conditions	ECOlevel > 4 ppm		p-value
	No (n=316)	Yes (n=139)	
Decayed teeth, n (%)			0.839
No	97 (30.7)	44 (31.7)	
Yes	219 (69.3)	95 (68.3)	
Missing teeth, n (%)			0.737
No	156 (49.4)	71 (50.6)	
Yes	160 (51.1)	68 (48.9)	
Filled teeth, n (%)			<0.001[b]
No	167 (52.8)	100 (71.9)	
Yes	149 (47.2)	39 (28.1)	
Gingival bleeding, n (%)			0.036[b]
No	117 (37.0)	66 (47.5)	
Yes	199 (63.0)	73 (52.5)	
Dental calculus, n (%)			0.464
No	308 (97.5)	137 (98.6)	
Yes	8 (2.5)	2 (1.4)	
Dental calculus with bleeding, n (%)			0.046[b]
No	28 (8.9)	5 (3.6)	
Yes	288 (91.1)	134 (96.4)	
Shallow periodontal pockets, n (%)			0.065
No	242 (76.6)	95 (68.3)	
Yes	74 (23.4)	44 (31.7)	
Deep periodontal pockets, n (%)			0.537
No	128 (92.1)	424 (93.2)	
Yes	11 (7.9)	31 (6.8)	
Mild dental debris deposit, n (%)			0.855
No	6 (1.9)	3 (2.2)	
Yes	310 (98.1)	136 (97.8)	
Moderate dental debris deposit, n (%)			0.101
No	142 (44.9)	51 (36.7)	
Yes	174 (55.1)	88 (63.3)	
Heavy dental debris deposit, n (%)			0.017[b]
No	293 (92.7)	119 (85.6)	
Yes	23 (7.3)	20 (14.4)	
Decayed teeth, mean rank	224.9	235.05	0.439
Missing teeth, mean rank	231.27	220.56	0.389
Filled teeth, mean rank	241.03	198.38	<0.001[a]
Bleeding gingiva, mean rank	239.84	201.08	0.003[a]
Dental calculus, mean rank	228.75	226.29	0.468
Dental calculus with bleeding, mean rank	221.29	243.25	0.096
Shallow periodontal pockets, mean rank	221.73	242.26	0.046[a]
Deep periodontal pockets, mean rank	226.89	230.52	0.534
Mild dental debris deposits, mean rank	230.06	223.33	0.609
Moderate dental debris deposits, mean rank	222.18	241.23	0.134
Heavy dental debris deposits, mean rank	223.06	239.23	0.017[a]

[a]Mann-Whitney U test; [b]Chi-square test.

Table 5
Age-adjusted odds of an ECO level > 4 ppm associated with selected oral health conditions on multivariable logistic regression analysis (*N*=455).

Oral health conditions	Age-adjusted odds ratio (95% CI)	*p*-value
Heavy dental debris deposits (yes/no)	2.154 (1.134-4.092)	0.019*
Dental calculus with bleeding (yes/no)	3.224 (1.156-8.989)	0.025*
Shallow periodontal pockets (sextant)	1.278 (1.066-1.534)	0.008*

*Statistically significant ($p<0.05$).

2010; Bailey, 2013). However, our study is in disagreement with some studies who recommended an ECO cut-off level of 3 ppm (Javors *et al*, 2005; Cropsey *et al*, 2006), 4.5-5 ppm (Low *et al*, 2004; Park *et al*, 2007; Maclaren *et al*, 2010; Marrone *et al*, 2011; Chatrchaiwiwatana and Ratanasiri, 2017), 5.5 ppm (Kapusta *et al*, 2010), 6 ppm (Middleton and Morice, 2000), 6.5 ppm (Deveci *et al*, 2004), 7 ppm (Hewat *et al*, 1998; Nakayama *et al*, 1998; Chatrchaiwiwatana and Ratanasiri, 2008), and 8 ppm (Jarvis *et al*, 1987; Crowley *et al*, 1989).

Our findings of a significant association between an ECO level ≥ 4 ppm and periodontitis was similar to some previous studies (Arbes Jr *et al,* 2001; Yamamoto *et al*, 2005; Nishida *et al*, 2008; Erdemir *et al*, 2010), but different from a study from Japan (Tanaka *et al,* 2013). We did not find a significant association between an an ECO level > 4 ppm and dental caries, unlike several previous studies (Williams *et al*, 2000; Aligne *et al,* 2003; Ayo-Yusuf *et al*, 2007). Our finding of a significant association between ECO level ≥ 4 ppm and the presence of heavy debris deposits and calculus with bleed has not been previously reported before. However, our finding that smokers had worse calculus formation and bleeding and worse debris deposits and this can procede periodontitis and had been reported in previous studies (Bergström *et al*, 2000; Chatrchaiwiwatana, 2003; Chatrchaiwiwatana, 2007; Gautam *et al*, 2011).

Our finding that an ECO level ≥ 4 ppm is associated with a number of oral health conditions among Thai adults is similar to the finding of a smaller study among Thai adults (Chatrchaiwiwatana and Ratanasiri, 2011). The large sample size in our study allowed for greater statistical power to assess potential associations between an ECO level and oral health conditions.

In conclusion, our findings among Thai adults showed ECO levels may be used among Thai subjects to evaluate tobacco smoking and be evaluated in association with oral health conditions.

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