

Determination of an Optimal Exhaled Carbon Monoxide (eCO) Cut-off for Smoking Status Classification among Undergraduate Students at Walailak University, Thailand: A Cross-Sectional Study

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Abstract

Smoking and secondhand smoke remain major public health concerns, contributing to chronic diseases and long-term health effects, particularly among university students at risk of initiating smoking. Measurement of exhaled carbon monoxide (eCO) is a simple, rapid, and non-invasive method that reflects recent tobacco smoke exposure. This study aimed to assess smoking behaviours among 1st-4th year students at Walailak University—classified as active smokers, passive smokers, and non-smokers using a self-reported questionnaire—and to compare these findings with eCO levels measured by a portable breath analyzer (Smokerlyzer). A total of 346 consenting students participated in this cross-sectional study. End-expiratory carbon monoxide concentrations were measured, and questionnaire data were collected to assess smoking behaviours and common sources of carbon monoxide exposure. Smokers were classified as the carbon monoxide-exposed group and compared with passive smokers and non-smokers. All participants completed the questionnaire. Active smokers ($n = 26$) demonstrated significantly higher eCO levels than passive smokers ($n = 62$) and non-smokers ($n = 258$), with median levels of 4.00, 1.00, and 1.00 ppm, respectively. Receiver operating characteristic (ROC) analysis identified an optimal eCO cut-off value of ≥ 2.50 ppm for distinguishing smokers from non-smokers and passive smokers, with an AUC of 0.719 (95% CI: 0.605-0.833, $p < 0.001$), sensitivity of 87.50%, and specificity of 77.80%. Most smokers expressed an intention to quit, and many students supported implementing a tobacco-free campaign within the university. In conclusion, eCO measurement provides rapid and objective results that may reflect recent tobacco smoke exposure. Integrating eCO screening with education on smoking-related diseases and types of tobacco smoke may strengthen smoking prevention strategies and support the development of a tobacco-free university environment.

Keywords: Smoking, Young adults, Student, Exhaled carbon monoxide, eCO

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ค่าตัดที่เหมาะสมของคาร์บอนมอนอกไซด์ในลมหายใจออกเพื่อจำแนกสถานะการสูบบุหรี่ใน นักศึกษาระดับปริญญาตรี มหาวิทยาลัยวลัยลักษณ์ ประเทศไทย: การศึกษาแบบภาคตัดขวาง

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บทคัดย่อ

การสูบบุหรี่และการได้รับควันบุหรี่มือสองเป็นปัญหาสาธารณสุขที่สำคัญ ซึ่งก่อให้เกิดโรคเรื้อรังและผลกระทบต่อสุขภาพในระยะยาว โดยเฉพาะในกลุ่มนักศึกษา ซึ่งเป็นวัยที่มีโอกาสเริ่มพฤติกรรมการสูบบุหรี่ การตรวจวัดระดับคาร์บอนมอนอกไซด์ที่หายใจออก (exhaled carbon monoxide, eCO) เป็นวิธีการที่ง่าย รวดเร็ว และสะท้อนถึงการสัมผัสควันบุหรี่ได้อย่างมีประสิทธิภาพ การศึกษานี้จึงมีวัตถุประสงค์เพื่อศึกษาพฤติกรรมการสูบบุหรี่ของนักศึกษามหาวิทยาลัยวลัยลักษณ์ ชั้นปีที่ 1-4 แบ่งเป็นผู้สูบบุหรี่ ผู้ได้รับควันบุหรี่มือสอง และผู้ไม่สูบบุหรี่ โดยใช้แบบสอบถามรายงานตนเอง และเปรียบเทียบกับค่า eCO โดยใช้เครื่องวิเคราะห์ลมหายใจแบบพกพา (Smokerlyzer) วัดค่าคาร์บอนมอนอกไซด์ในลมหายใจตอนสิ้นสุดการหายใจออกในกลุ่มตัวอย่างที่ยินยอมเข้าร่วมการศึกษา จำนวน 346 คน เก็บข้อมูลด้วยแบบสอบถามเพื่อประเมินผลกระทบจากแหล่งกำเนิดก๊าซคาร์บอนมอนอกไซด์ทั่วไปที่พบบ่อย โดยใช้กลุ่มผู้สูบบุหรี่เป็นกลุ่มสัมผัสคาร์บอนมอนอกไซด์ และเปรียบเทียบกับผู้ไม่สูบบุหรี่และผู้ได้รับควันบุหรี่มือสอง ผลการศึกษาพบว่าผู้เข้าร่วมการศึกษารวม 346 คนตอบแบบสอบถามครบถ้วน ผู้สูบบุหรี่ ($n = 26$) มีระดับ eCO สูงกว่าผู้ได้รับควันบุหรี่มือสอง ($n = 62$) และผู้ไม่สูบบุหรี่ ($n = 258$) อย่างมีนัยสำคัญ (ค่ามัธยฐาน: 4.00, 1.00 และ 1.00 ppm ตามลำดับ) การวิเคราะห์เส้นโค้ง ROC (receiver operating characteristic curve) แสดงให้เห็นว่าค่าระดับ eCO ≥ 2.50 ppm เป็นจุดตัดที่เหมาะสมสำหรับการจำแนกผู้สูบบุหรี่ โดยมีพื้นที่ใต้โค้ง (area under the curve; AUC) เท่ากับ 0.719 (95% CI: 0.605-0.833, $p < 0.001$) ความไวเท่ากับร้อยละ 87.50 และความจำเพาะเท่ากับร้อยละ 77.80 นอกจากนี้ ผู้สูบบุหรี่ส่วนใหญ่มีความตั้งใจที่จะเลิกบุหรี่ และนักศึกษาจำนวนมากแสดงความต้องการให้มีการรณรงค์ปลอดบุหรี่ในมหาวิทยาลัย ผลการวิจัยสรุปได้ว่าการวิเคราะห์ลมหายใจสามารถให้ผลการตรวจได้อย่างรวดเร็ว และสามารถใช้ในการประเมินการสัมผัสคาร์บอนมอนอกไซด์ที่เกี่ยวข้องกับพฤติกรรมการสูบบุหรี่ รวมถึงการใช้ระดับ eCO ร่วมกับความรู้เกี่ยวกับโรคที่เกิดจากการสูบบุหรี่และประเภทของควันบุหรี่ อาจช่วยสนับสนุนการป้องกันการสูบบุหรี่ การเฝ้าระวังพฤติกรรมการสูบบุหรี่ และการพัฒนาสภาพแวดล้อมปลอดบุหรี่ภายในมหาวิทยาลัยได้อย่างเหมาะสม

คำสำคัญ: การสูบบุหรี่ วัยผู้ใหญ่ตอนต้น นักศึกษา การตรวจวัดระดับคาร์บอนมอนอกไซด์ที่หายใจออก eCO

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1. Introduction

Smoking is one of the major causes of preventable diseases, which is one of the biggest public health threats in the world. Tobacco smoke contains in excess of 7,000 synthetic substances and compounds. Hundreds of these are dangerous and cause in excess of 70 diseases, such as cancer.⁽¹⁾ Cigarette smoking is the cause of diseases that impair the functions of the body and premature mortality. Levels of smoking prevalence are increasing for both men and women annually. In conventional cigarettes, tobacco combustion is known to release nicotine together with a multitude of harmful and potentially harmful chemical constituents (HPHCs), including carbon monoxide (CO).⁽²⁾

CO is a colorless, odorless gas produced from incomplete combustion of fossil fuels. The affinity of CO for hemoglobin is about 240 times that of oxygen, and this accounts for at least some of its toxic effects.^(3,4) CO is contained in mainstream smoke from cigarettes (3-4%),⁽⁵⁾ and blood carboxyhemoglobin (CO-Hb) saturation increases approximately 10-15% in heavy smokers.⁽⁶⁻⁸⁾

Following inhalation, CO displaces oxygen in the erythrocyte to form carboxyhemoglobin (CO-Hb). In this form, CO has a half-life of about 5 to 6 h^(9,10) and may remain in the blood for up to 24 h depending on a number of factors such as gender, physical activity, and ventilation rate.^(11,12) While some exposure to CO may occur in normal day-to-day life due to environmental pollutions from passive smoking and occupational exposure, the most likely cause of high levels of exposure is from smoking.⁽¹³⁾

In Thailand, tobacco use remains a major public health concern, particularly among adolescents and young adults. Recent national reports indicate that smoking and the use of alternative tobacco products, especially electronic cigarettes, are increasingly common among university-aged populations. Despite the implementation of smoke-free policies, exposure to secondhand smoke remains prevalent in public and educational settings. These findings underscore the need for effective smoking surveillance, prevention programs, and tobacco control strategies among university students in Thailand.^(14,15)

Measurement of exhaled CO (eCO) is widely used to assess smoking status because CO from cigarette smoke is rapidly absorbed into the bloodstream during inhalation. Previous studies have demonstrated that eCO monitoring is a rapid, non-invasive, and practical approach with acceptable sensitivity and specificity for identifying recent tobacco smoke exposure.⁽¹⁶⁻¹⁸⁾ In addition, eCO assessment provides an objective biomarker that may improve the accuracy and reliability of smoking status classification compared with self-reported smoking behavior alone, particularly in populations where underreporting of smoking is common. Consequently, eCO testing has been increasingly applied in smoking prevention programs, smoking cessation interventions, and both clinical and community-based research settings.^(19,20) The aim of this study was to apply the eCO test as a tool for a smoke-free environment campaign among undergraduate students by estimating baseline eCO levels, examining the sensitivity and specificity of the eCO test, and defining the optimal cut-off value from recent smoking assessments among a sample of undergraduate students at Walailak University, Nakhon Si Thammarat Province.

2. Methods

2.1 Study population

This cross-sectional study was conducted among undergraduate students enrolled in the 1st-4th academic years at Walailak University, Thailand. The target population consisted of university students aged 18 years or older who were willing to participate in the study during the study period. Participants were recruited using a convenience sampling method. The inclusion criteria were: (1) undergraduate

students currently enrolled at the university, (2) age ≥ 18 years, and (3) willingness to participate and provide written informed consent. The exclusion criteria included: (1) inability to perform the breath test correctly, (2) history of respiratory conditions or acute illness that could interfere with eCO measurement, and (3) incomplete questionnaire data. The sample size was determined based on participant availability during the study period and was considered sufficient for comparative analysis among smoking-status groups and receiver operating characteristic (ROC) analysis. A total of 346 students were included in the final analysis.

2.2 Operational definitions of study groups

Participants were classified into three groups based on self-reported smoking behavior and exposure history obtained from the questionnaire:

- 2.2.1 Active smokers: participants who reported current cigarette smoking or use of tobacco products during the study period.
- 2.2.2 Passive smokers: participants who did not actively smoke but reported regular exposure to secondhand tobacco smoke from family members, friends, or surrounding environments.
- 2.2.3 Non-smokers: participants who reported no current smoking behavior and no regular exposure to secondhand smoke.

Smoking characteristics, including smoking frequency, duration of smoking, number of cigarettes smoked per day, and nicotine dependence assessed using the Fagerström Test for Nicotine Dependence (FTND), were also recorded.

2.3 Questionnaire

Surveys were distributed to the students after they provided informed consent, and they were asked to answer the survey questions by themselves and not to write their names and numbers. In the conducted survey, the following information were collected: student demographic characteristics; smoking addiction of their families, their friends, and themselves; reasons for starting to smoke, whether they want to quit smoking, whether they have tried to quit smoking, and which of the organs that they know are harmed by smoking. Active smokers were asked to complete the Fagerström Test of Nicotine Dependence (FTND). All participants underwent measurement for an eCO level, and the results were informed immediately with short advices.

2.4 Breath CO Monitoring

Breath CO monitoring was performed using the EC50 Smokerlyzer (Bedfont Instruments; Kent, UK), a portable and non-invasive carbon monoxide monitor that has been widely used for smoking assessment and smoking cessation research.⁽¹⁹⁾ The Smokerlyzer measures eCO concentrations in parts per million (ppm) using an electrochemical sensor system. During breath holding, carbon monoxide in the bloodstream reaches equilibrium with alveolar air, resulting in a strong correlation between eCO concentrations and blood carboxyhemoglobin (CO-Hb) levels.^(21,22)

This enables the Smokerlyzer to accurately estimate the blood CO-Hb concentration from the breath CO level. The Smokerlyzer was calibrated weekly using a mixture of 50 ppm CO in air. To standardize the breath being analyzed by the Smokerlyzer, the subjects were asked to exhale completely, inhale fully, and then hold their breath for 15 s. If the subjects were unable to hold their breath for 15 s, they were asked to hold it for as long as possible and the length of time was recorded. Following the breath holding, the subjects were asked to exhale slowly into the Smokerlyzer and were encouraged to exhale fully in order to sample the alveolar air.

2.5 Statistical Analysis

All statistical analyses were performed using SPSS version 10.0. eCO levels were presented as median and interquartile range (IQR). Differences in eCO levels among the three groups were analyzed using the Kruskal-Wallis test. Receiver operating characteristic (ROC) curve analysis was used to determine the optimal eCO cut-off value, and the area under the curve (AUC), sensitivity, specificity, and 95% confidence interval (95% CI) were calculated. Spearman correlation analysis was used to assess the relationships between eCO levels and smoking characteristics. A $p < 0.05$ was considered statistically significant.

2.6 Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethical Clearance Committee on Human Rights Related to Research Involving Human Subjects at Walailak University (WUEC-19-180-01). Written informed consent was obtained from all participants prior to participation.

3. Results

3.1 Breath CO Monitoring

Breath CO levels were assessed in a total of 346 people: exhaled CO was detectable in all subjects; 258 of them were non-smokers (124 men, 134 women; mean age 20.05 ± 1.42 years), 62 were passive smokers (35 men, 27 women; mean age 20.02 ± 1.35 years), and 26 were smokers (24 men, 2 women; mean age 21.38 ± 0.74 years). The median eCO level in active smokers was 4.00 ppm, passive smokers was 1.00, and non-smokers was 1.00. As expected, the eCO levels were significantly higher in active smokers compared with passive smokers and non-smokers ($p < 0.01$) (Table 1).

3.2 Smoking behavior

From the questionnaire, most of the students were non-smokers but familiar with smokers (80.63%). In total, 8 of 26 smokers were persuaded by family members or other smokers (30.77%). The frequency of smoking every 13-24 hours (once a day) was 34.62%, every 7-12 hours was 15.38%, every 5-6 hours was 19.23%, every 3-4 hours was 19.23%, and every 1-2 hours was 11.54%. We found that 87.57% of the students who participated in the study have no diseases from smoking. In addition, 88.46% of the smokers usually smoked in the university, and 92.31% of them wanted to quit smoking (Table 2).

3.3 Correlations between exhaled carbon monoxide (eCO) level and smoking characteristics

Our results showed that there was a significant positive correlation between frequency of smokers and eCO levels, and between the duration of smoking and eCO levels in smokers (Table 3). Moreover, our results showed that smokers with longer smoking duration and higher smoking frequency tended to have higher eCO levels (Table 4). However, no significant associations were observed between eCO levels, daily cigarette consumption, and FTND score.

3.4 Background knowledge on tobacco smoking and opinion on anti-smoking campaign from respondents

The background knowledge on tobacco smoking from three study groups by the questionnaire-based interview showed that most of the students knew the definition of first-hand smoke (91.04%), secondhand smoke (95.09%), and thirdhand smoke (59.25%). The health risks from tobacco smoking that the participants mostly knew about were lung cancer (98.55%), emphysema (73.70%), asthma (73.12%), oral cancer (57.51%), cardiovascular disease (52.31%), erectile dysfunction (47.98%), stroke (40.75%),

hypertension (37.28%), esophageal cancer (36.71%), and diabetes (16.47%) (Table 5). Most of the students (97.98%) supported implementing an anti-smoking campaign at the university (Table 6).

Table 1 Demographic characteristics and exhaled carbon monoxide (eCO) levels of the participants.

Characteristics	Tobacco smoking		
	Active smokers (n = 26)	Passive smokers (n = 62)	Non-smokers (n = 258)
Age, year (mean ± SD)	21.38 ± 0.74	20.02 ± 1.35	20.05 ± 1.42
Gender, n (%)			
Male	24 (92.31%)	35 (56.45%)	124 (48.06%)
Female	2 (7.69%)	27 (43.55%)	134 (51.94%)
eCO level, n			
1 ppm	4	47	216
2 ppm	2	14	40
3 ppm	2	0	1
4 ppm	4	1	0
5 ppm	1	0	1
6 ppm	3	0	0
7 ppm	1	0	0
8 ppm	3	0	0
9 ppm	2	0	0
10 ppm	1	0	0
12 ppm	1	0	0
15 ppm	1	0	0
38 ppm	1	0	0
eCO level (ppm), median (IQR)	4.00 (2.8-8.3) ^{a,b}	1.00 (1.0-1.0)	1.00 (1.0-1.0)

^a Significant difference in eCO level at $p < 0.01$, compared with non-smokers.

^b Significant difference in eCO level at $p < 0.01$, compared with passive smokers.

Table 2 Smoking behavior.

Smoking behavior of students	n	%
Active smokers (n = 26)		
<i>Frequency of smoking (days per week)</i>		
1-3	12	5.00
4-6	6	2.00
7	8	2.30
<i>Smoking frequency</i>		
Every 1-2 hrs	3	11.54
Every 3-4 hrs	5	19.23
Every 5-6 hrs	5	19.23
Every 7-12 hrs	4	15.38
Every 13-24 hrs (once a day)	9	34.62
<i>Smoking duration</i>		
< 1 year	3	11.54
1 year	12	46.15
2 years	3	11.54
3 years	3	11.54
4 years	2	7.69
5 years	3	11.54
6 years	1	3.85
7 years	1	3.85
<i>Smoking in the university</i>		
Yes	23	88.46
No	3	11.54
<i>Family member or smoker persuaded participant to smoke</i>		
Yes	8	30.77
No	18	69.23
<i>Wanting to quit smoking</i>		
Yes	24	92.31
No	2	7.69
Non-smokers and passive smokers (n = 320)		
<i>Familiar with smokers</i>	258	80.63
<i>Not familiar with smokers</i>	62	19.37
Smoking-related diseases awareness (n = 346)		
No	303	87.57
Not sure	41	11.85
Yes, such as lung cancer, oral cancer, esophageal cancer, emphysema, cardiovascular disease, stroke, asthma, diabetes, hypertension, and erectile dysfunction	2	0.58

Table 3 Correlations between exhaled carbon monoxide (eCO) level and smoking characteristics.

Correlations with eCO levels	r	p
Frequency of smokers	0.263	0.000 ^a
Frequency of smoking (per day)	0.247	0.158
Duration of smoking habit	0.538	0.004 ^a
Number of cigarettes smoked per day	-0.086	0.890
Fagerström Test of Nicotine Dependence (FTND) score	0.183	0.325

^a Significant correlation at $p < 0.01$.

Table 4 Exhaled carbon monoxide (eCO) levels in active smokers.

Characteristics	n	Mean eCO level (ppm)
Number of cigarettes smoked per day		
1-5	20	5.55
6-10	4	14.25
11-15	1	6
Frequency of smoking per day (hours)		
1-2	3	7.67
3-4	5	12.00
5-6	5	6.00
7-12	4	5.50
13-24	9	2.22
Fagerström Test of Nicotine Dependence (FTND) score		
0-3	21	4.10
4-5	5	8.29
6-7	0	0.00
8-9	0	0.00
10	0	0.00

Table 5 Background knowledge on tobacco smoking among all participants from the questionnaire-based interview. (N = 346)

Background knowledge	n	%
Disease risks from smoking		
Lung cancer	341	98.55
Emphysema	255	73.70
Asthma	253	73.12
Oral cancer	199	57.51
Cardiovascular disease	181	52.31
Erectile dysfunction	166	47.98
Stroke	141	40.75
Hypertension	129	37.28
Esophageal cancer	127	36.71
Diabetes	57	16.47
Types of tobacco smoke (n, %)		
Second-hand smoke	329	95.09
First-hand smoke	315	91.04
Third-hand smoke	205	59.25

Table 6 Opinion on anti-smoking campaign from respondents.

Opinion on anti-smoking campaign from respondents	n = 346	(%)
Agree	339	97.98
Disagree	7	2.02

3.5 Receiver Operating Characteristic (ROC) Curve

The median duration of smoking at two years was used to distinguish smokers from non-smokers by eCO level. We found that the appropriated cut-off was ≥ 2.5 ppm. From Fig. 1. shown, the AUC of the eCO level in smokers at 95% confidence was 0.719 at the cut-off ≥ 2.5 ppm (95% CI: 0.605-0.833, $p < 0.001$), and the sensitivity and specificity were 87.50% and 77.80%, respectively, indicating an acceptable diagnostic accuracy for predicting smoking status.

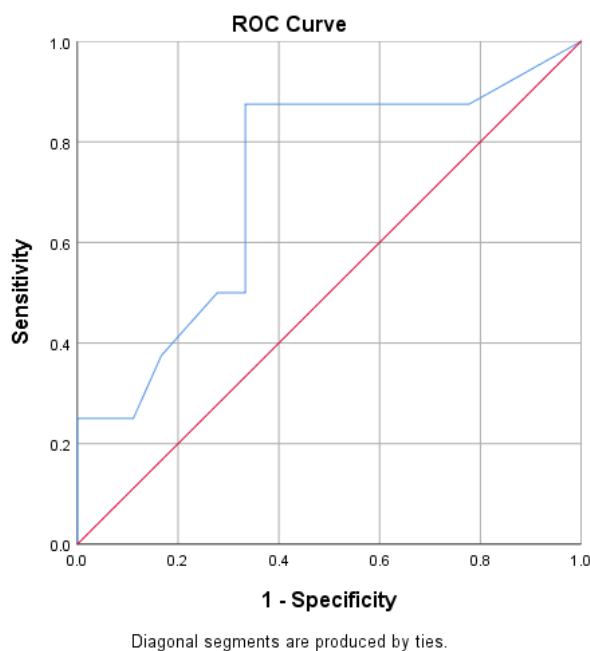


Fig. 1 Receiver operating characteristic (ROC) curve. 1-specificity (x-axis) was plotted against sensitivity at duration of smoking from <1 year to 7 years. Area under curve (AUC) was calculated.

4. Discussion

In the present study, ROC curve analysis demonstrated that the optimal cut-off value for eCO in distinguishing smokers from non-smokers was ≥ 2.5 ppm, with the sensitivity of 87.50% and the specificity of 77.80%. The AUC was 0.719, indicating acceptable discriminatory ability for predicting smoking status. These findings suggest that eCO measurement using the Smokerlyzer may serve as a practical, rapid, and non-invasive screening tool for identifying smoking behavior among university students and young adults.^(18,19) The relatively high sensitivity observed in this study indicates that the selected cut-off was effective in identifying active smokers, whereas the moderate specificity suggests that some non-smokers or passive smokers may also present elevated eCO levels. This may be attributable to environmental carbon monoxide exposure, including secondhand smoke, air pollution, and indoor smoke exposure.

The cut-off value identified in the present study was lower than those reported in several previous studies involving adult smokers, which commonly reported eCO cut-off values ranging from 4-7 ppm.^(19,20) Differences in smoking intensity, smoking duration, participant characteristics, environmental exposure, and timing of smoking before testing may explain this variation. Since the present study primarily involved young adults with relatively low smoking intensity and short smoking duration, lower baseline eCO concentrations may have contributed to the lower optimal threshold. In addition, recent recommendations regarding exhaled breath biomarker standardization have emphasized the importance of controlling environmental and procedural factors during eCO assessment to improve measurement reliability.⁽²¹⁾

In the present study, eCO levels measured using the Smokerlyzer were significantly higher in smokers than in non-smokers, which was consistent with previous findings among university students and young adults.^(18,22) However, no significant difference in eCO levels was observed between passive smokers and

non-smokers, similar to findings from previous studies investigating secondhand smoke exposure and respiratory biomarkers.^(23,24) Environmental exposure to carbon monoxide and variability in recent smoke exposure may partly explain the overlapping eCO concentrations observed between these groups.

Analysis of smoking behaviors revealed that most smokers used conventional cigarettes because they were easily accessible from convenience stores. Some participants also reported using alternative tobacco products, including rolled tobacco and electronic cigarettes. These findings are consistent with recent studies demonstrating increasing use of multiple tobacco and nicotine products among university students and young adults.^(25,26) The questionnaire findings also demonstrated that most smokers intended to quit smoking. The major reasons for smoking cessation included concerns regarding the harmful health effects of smoking, family encouragement, economic burden, and smoking-related diseases. Similar findings have been reported in previous studies evaluating smoking perceptions and quitting intentions among young adults.⁽²⁷⁾

Regarding tobacco-related knowledge, most participants recognized lung cancer, emphysema, asthma, and cardiovascular disease as major health risks associated with smoking. This finding was consistent with previous studies reporting increased awareness of smoking-related diseases among university students and young adults.⁽²⁷⁾ In addition, most respondents (more than 91%) were aware of firsthand and secondhand smoke exposure, suggesting generally adequate baseline knowledge regarding tobacco-related health risks.

Nevertheless, our results demonstrated no significant correlation between eCO levels and smoking characteristics, including smoking frequency, number of cigarettes smoked per day, and FTND score. These findings differ from those reported by Sinthupibulyakit *et al.*⁽²²⁾, who observed positive correlations between eCO levels, smoking duration, daily cigarette consumption, smoking frequency, and FTND score. The discrepancy may be attributable to differences in smoking duration, smoking intensity, sample size, and participant characteristics between studies. Furthermore, environmental and measurement-related factors may have reduced the specificity of eCO as a biomarker of active smoking in the present study. Smoking immediately before testing may markedly increase eCO concentrations, potentially obscuring differences between active smokers, passive smokers, and non-smokers. Future studies should standardize the interval between the last cigarette and eCO measurement, assess recent environmental exposures, and consider complementary biomarkers, such as cotinine to improve smoking status classification and diagnostic accuracy.^(20,21)

More than 97% of the students supported implementation of anti-smoking campaigns at the university. These findings are consistent with previous studies demonstrating positive attitudes toward tobacco-free campus policies and smoking prevention programs among university students.⁽²⁸⁻³⁰⁾ Therefore, the incorporation of eCO testing into smoke-free university campaigns may help increase awareness of the harmful effects of smoking, encourage smoking cessation, and potentially reduce smoking prevalence among young adults in the long term.

5. Conclusion

The eCO test provided a simple, non-invasive, rapid, and inexpensive method for assessing smoking status. It may serve as a useful tool for increasing awareness of the harmful effects of smoking among undergraduate students, particularly smokers. Our findings suggest that an eCO level at ≥ 2.5 ppm may be used as a preliminary cut-off value for identifying smokers with high sensitivity and specificity. In addition,

eCO measurement could support smoking behavior surveillance, smoking cessation counseling, and monitoring of tobacco control measures within the university setting. Furthermore, knowledge regarding smoking-related diseases and smoke exposure may contribute to smoking prevention efforts and support the development of a tobacco-free university environment.

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