

Evaluation of smoking status: comparison of self-reports with exhaled carbon monoxide analysis in university students in the Islamic Republic of Iran

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Abstract

Background: Smoking is considered the leading risk factor for many chronic diseases and deaths worldwide. Thus, it is important to determine the number of smokers before implementing tobacco control initiatives. Due to stigma and deterrent measures, it is impossible to access smokers through a self-report questionnaire.

Aims: To compare exhaled carbon monoxide levels with self-reports among university students in the Islamic Republic of Iran.

Methods: This cross-sectional study included a convenience sample of 60 university students recruited in 2016 in Tehran. There were 30 women and 30 men with an average age of 23.1 (± 15.6) years. They were interviewed using an adaptation of the International Union Against Tuberculosis and Lung Diseases questionnaire and further assessed by breath analysis. Smoking status was compared and then correlated with the resultant carbon monoxide levels at a cutoff of 6 ppm.

Results: Mean cigarette consumption was 4.7 (± 1.8) each day and smoking status was reported as 19 (31.7%) current smokers and 41 (68.3%) nonsmokers of tobacco. Significant correlations were obtained between the exhaled carbon monoxide levels of the smoker and nonsmoker groups ($P < 0.05$). Irrespective of the measures of smoking status, the frequency of detecting smokers was comparable to that of detecting nonsmokers ($P = 0.756$).

Conclusions: Similar to self-reports, the exhaled carbon monoxide measurement successfully distinguished smokers from nonsmokers. This allows healthcare providers and policy-makers to examine the effectiveness of tobacco cessation and prevention programmes.

Keywords: exhaled carbon monoxide, tobacco use, self-report, university students, Islamic Republic of Iran

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Introduction

Smoking is the most prevalent, high-cost, and fatal form of drug dependence. Each year, > 8 million of the estimated global 1.1 billion tobacco smokers die due to the use of nicotine-containing products (1). Mathers and Loncar (2) have reported that tobacco-related deaths will reach 8.3 million in 2030. Tobacco consumption accounts for 80–90% of lung cancers (3) and leads to an increase in cancers of the larynx, mouth, oesophagus, pancreas, kidney, bladder, and uterine cervix (4). In addition to cardiovascular and respiratory diseases, it can cause fetal abnormalities (1). Deaths caused by tobacco use are more than those linked to alcohol consumption, AIDS, vehicle accidents, substance abuse, crime and suicide combined (5). Tobacco use has grown in low- and middle-income countries, and ~80% of smokers live in these regions (6). The tobacco use epidemic has shifted to the developing world. Given the young population density, the Islamic Republic of Iran demands special attention (7); in other words, the high number of adolescents in the country makes it into an ideal market for the tobacco trade.

Determining smoking status is important in starting cessation interventions as well as monitoring progress (8). In epidemiological studies, validation and confirmation of cigarette smoking and nonsmoking are essential. The advent of electronic health records has facilitated obtaining updates on smoking status. However, this may not occur in reality due to the absence of approved terminology and granularity for data collection, changes in cultural attitudes toward tobacco use, and probable instability of smoking behavior (9,10). Tobacco exposure can be assessed by self-reports, which seem convenient, especially for extensive studies (11). Although self-reported smoking status is widely applied for assessing the prevalence of smoking, it underestimates the actual exposure (12), owing to the lack of social acceptance of smoking (13).

As an alternative, many studies have used measurement of carbon monoxide (CO) in exhaled breath as a quick and noninvasive technique to verify smoking status (14). CO is a product of tobacco combustion (15), and exhaled CO is considered a specific biomarker of recent

smoking, with a half-life of 2–6 hours (16). Accordingly, the present study compared the self-reported cigarette smoking status with the results of exhaled CO testing in university students. This is believed to be the first study in the Islamic Republic of Iran to investigate the correlation between exhaled CO and self-reports of smoking.

Methods

Study design and participants

This was a cross-sectional study conducted within a university setting. In November 2016, we used a nonrandom convenience sampling technique to select 60 students who read the study communiqués issued by the Department of Public Relations in the School of Advanced Technologies in Medicine in Tehran, Islamic Republic of Iran. The recruitment was performed in person by research team members based on the following inclusion criteria: age 18–30 years and higher education to at least diploma level. There was an equal sex ratio, with 30 women and 30 men, with an average age of 23.09 [standard deviation (SD) 15.64] years. The exclusion criteria included pulmonary diseases, cognitive disorders, nicotine replacement therapy, renal failure requiring dialysis, and facial deformities that would cause problems in the use of spirometry or determination of the exhaled CO level (17).

Determination of self-reported smoking status

A self-administered Farsi-language smoking questionnaire, adapted from the International Union Against Tuberculosis and Lung Diseases (18,19), was utilized, as in previous reports from the Islamic Republic of Iran (20). The questionnaire contained information on demographics (age, residency and marriage) and tobacco use (4 questions), smoking status (4 questions), and smoking frequency (4 questions). Two supplementary questions were added concerning the age at starting smoking tobacco. Six of the questions dealt with the pattern of smoking behavior, including one “yes/no” question about present cigarette smoking; 2 short answer questions about weekly frequency of cigarette smoking; 2 short answer questions about the type of cigarettes smoked; and 1 “multiple-choice question” about the time to first cigarette in the morning (ranging from < 5 minutes to > 1 hour).

Exhaled breath CO analyzer

The piCO+ Smokerlyzer (Bedfont Scientific, Maidstone, UK) was used to measure exhaled CO levels with standardized smoking thresholds recommended by the manufacturer for different age categories. The test was conducted in the school hall by a trained research assistant. There was a breath sampling D-piece and a cardboard mouthpiece attached to the device before each test. Initially, the ambient levels of CO were detected, and the machine was calibrated against the room air. The study participants were instructed to inhale and hold their breath while a 15-second countdown was started. Also, they were asked to blow into the mouthpiece as slowly and thoroughly as possible in an attempt to empty the

lungs when the device alarm started. Finally, the students were given access to their test results. The breath tests were conducted in duplicate to ensure consistency. The breath analysis was repeated if the difference between the results was higher than 2 ppm. The exhaled CO levels were presented in ppm, with > 6 ppm being indicative of smoking.

Procedure

All participants were referred during November 2016 to the Health Counseling Room in the School of Advanced Technologies in Medicine for eligibility assessment by a physician and psychologist. The initial sample included 84 men and women, 60 of whom met the inclusion criteria. The other remaining 24 participants were prevented from continuing the study. Afterwards, the students were asked to participate in both interview and breath analysis. All interviewers were trained to ensure consistency and avoid bias. Those who reported any form of tobacco use in the preceding 24 hours were put in the category of smokers. The remaining students were considered nonsmokers, including those who did not smoke in the last week or who had never smoked.

Ethical considerations

At the start of the study, written informed consent was obtained from all students. They were assured that the results would be confidential and reported anonymously in an attempt to encourage accurate and thorough reporting of their smoking habits. The Research Ethics Committee of Tehran University of Medical Sciences approved the study (code: IR.TUMS.REC.1394.18.96).

Statistical analysis

Data were collected and entered into SPSS version 22 software (SPSS Inc., Chicago, IL, USA) for further analyses. The data were described by descriptive statistics, including frequency, percentage, and mean (SD). The data distribution was investigated by performing the Kolmogorov–Smirnov test. Student’s independent *t* test was carried out for comparison of CO levels between the smoker and nonsmoker groups. The Pearson correlation coefficient was determined between them. The frequency of smokers according to exhaled CO measurement was compared with that by self-reports using Pearson’s χ^2 test. The effect of sex on the exhaled CO levels was evaluated by the Mann–Whitney *U* test. $P < 0.05$ was defined as statistically significant.

Results

The demographic characteristics of the university students are summarized in Table 1. They had a mean cigarette consumption of 4.68 (1.79) each day, and a mean smoking initiation age of 19.43 (8.62) years.

Among the 60 students, 319 (1.67%) had smoked tobacco within the last 24 hours and were assigned to the smoker group. A total of 41 participants (68.33%) self-reported no use of tobacco products in the last week or no

Table 1 Participants' demographics and smoking characteristics

Characteristics	Self-reported status of tobacco use		Total n = 60
	Smoker n = 19 (31.67)	Nonsmoker n = 41 (68.33)	
Age, years, mean (SD)	25.68 ± 11.21	21.62 ± 19.04	23.09 ± 15.64
Male, n (%)	14 (23.33)	16 (26.67)	30 (50)
Residency, n (%)			
Individual home	8 (13.33)	25 (41.67)	33 (55.00)
Parent's home	5 (8.33)	8 (13.33)	13 (21.67)
Dormitory	6 (10.00)	8 (13.33)	14 (23.33)
Marriage, n (%)			
Divorced/widowed	1 (1.67)	1 (1.67)	2 (3.33)
Married	2 (3.33)	5 (8.33)	7 (11.67)
Single	11 (18.33)	34 (56.67)	45 (75.00)
Smoking initiation age, years, mean (SD)	17.93 ± 6.22	21.04 ± 13.51	19.43 ± 8.62
Cigarettes per day, mean (SD)	5.79 ± 3.40	4.11 ± 1.13	4.68 ± 1.79

Results presented as number (%) SD = standard deviation.

smoking at all, and they were placed in the nonsmoker group. In the smoker group, there were 14 (23.33%) men, aged 25.68 (11.21) years, and 11 (18.33%) were single. In the nonsmoker group, there were 16 (26.67%) men, aged 21.62 (19.04) years, and 34 (56.67%) were single. The smoker group tended to start smoking at a younger age compared with the nonsmokers [17.93 (6.22) vs 21.04 (13.51) years and reported smoking a higher number of cigarettes each day [5.79 (3.40) vs 4.11 (1.13)].

The participants in the smoker group had an exhaled CO level of 13.57 (2.03) ppm, which was about 3 times higher than 4.44 (0.52) ppm in the nonsmoker group. The independent-samples *t* test showed that there was a significant difference in exhaled CO levels between the groups ($t(58) = 19.84, P = 0.004$). Moreover, the Pearson correlation coefficient between the exhaled CO levels of the 2 groups was 0.719 ($P = 0.003$). These results indicated that exhaled CO in current smokers could be distinguished from that in ex- or nonsmokers. The CO analyzer showed that 15 students had an average CO level > 6 ppm. The χ^2 test revealed no marked association between the smoking status reported by the exhaled CO measurement and self-report ($\chi^2 = 0.657, P = 0.418$). In other words, the results of the exhaled CO measurement were in line with those of the self-report.

The exhaled CO levels were 8.80 (1.0) ppm for men and 5.90 (0.60) ppm for women. Based on the Mann-Whitney *U* test, the male participants had a significantly higher concentration of exhaled CO ($U = 47.000, P = 0.035$) than the female participants.

Discussion

The prevalence of tobacco use was 31.67% among university students, which is consistent with other reports from the Islamic Republic of Iran (21–23). The mean number of cigarettes per day and smoking initiation age were 4.68 (1.79) and 19.43 (8.62) years, respectively. No study has investigated the average number of cigarettes per day for university students. However, a recent meta-analy-

sis found a daily rate of 11.6 and 15.0 in Tehran Province (24). In the present study, men showed higher exhaled CO levels than the total participants (around 2-fold) and women (around 3-fold). These findings were consistent with the results reported by Moscato et al. (25); however, the CO values were not comparable between the studies. Typical exhaled CO values certainly differ across studies even if they used a piCO⁺ Smokerlyzer because mean levels in nonsmokers vary from < 1.5 ppm (26) to 3 ppm (27). These differences arise from factors such as disparity in environmental CO levels, anthropometric features (e.g., lung capacity), and measurement techniques (28). Raiff et al. showed that measures obtained from prolonged expiration led to higher values than those from shorter expiration (29). In this regard, the trend of the exhaled CO concentration during expiration may also play a role. Schober et al. suggested 3 phases for CO level (30). It is 0 in the primary part of the expiration (phase 1), followed by progressive increases (phase 2), and finally decreases after a plateau (phase 3). Moreover, considerable environmental CO levels could have explained the exhaled CO levels since our study was conducted in a large city, and the participants were exposed to air pollution caused by traffic jams, especially when traveling to the university. Individual subject variability [e.g., lung volume (28) and physical activity (31)] may influence CO measures but was not considered in our study.

The present study showed that the breath analysis device could be used for accurate determination of tobacco use in adolescents with light smoking (around 5 cigarettes/day). Additionally, this device provided a reasonable alternative to self-reporting. Measurement of exhaled CO using this device at a cutoff point of 6 ppm sounds like a viable measure for distinction between current smokers and ex- or nonsmokers, as opposed to the self-reporting method. These findings were corroborated by previous investigations (32,33).

This study had some limitations. The study dealt with a hidden problem in society, especially in universities; therefore, self-reported data faced challenges due to taboos

surrounding women's smoking. As a result, a combination questionnaire together with secret codes instead of names was used to reduce bias. Besides these, restrictions were undertaken to ensure data confidentiality. However, it is likely some of the participants might have avoided giving a socially undesirable response. Moreover, the cross-sectional study design made causal conclusions difficult. Small sample size was another limitation that should be resolved for future investigations. The use of biological measures like exhaled CO is associated with the limitation of measurement among different individuals and receiving false-positive reports. Other factors may have affected our results, such as a lack of financial resources, biological and social variations between the sexes, and poor collaboration from organizations. Additionally, a high number of questions took more time to respond than expected, which could have affected the

students' response precision. Also, the results of this study can only be generalized to the university students selected here.

In conclusion, the present study proposed that the exhaled CO levels measured by breath analysis could successfully discriminate current smokers from nonsmokers, which is the same as self-reporting. Moreover, the use of exhaled CO allows healthcare providers and policy-makers to implement MPOWER¹ measures, enhance the country-level achievements in interventions targeting the demand for tobacco products, and examine the effectiveness of tobacco use cessation and prevention programmes.

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Competing interests: None declared.

Évaluation du statut tabagique : comparaison des informations auto-déclarées avec la mesure du monoxyde de carbone expiré chez les étudiants universitaires en République islamique d'Iran

Résumé

Contexte : Le tabagisme est considéré comme le principal facteur de risque de nombreuses maladies chroniques et de décès dans le monde. Il est donc important de déterminer le nombre de fumeurs avant de mettre en œuvre des initiatives de lutte antitabac. En raison de la stigmatisation et des mesures dissuasives, il est impossible d'accéder aux informations concernant le nombre de fumeurs par le biais d'un questionnaire d'auto-déclaration.

Objectifs : Comparer les taux de monoxyde de carbone (CO) expiré avec les informations auto-déclarées par les étudiants universitaires en République islamique d'Iran.

Méthodes : La présente étude transversale a inclus un échantillon de commodité de 60 étudiants universitaires recrutés en 2016 à Téhéran. Il était composé de 30 femmes et de 30 hommes dont l'âge moyen était de 23,1 ans ($\pm 15,6$). Les entretiens avec les participants se sont déroulés en utilisant une version adaptée du questionnaire de l'Union internationale contre la tuberculose et les maladies respiratoires ; une évaluation ultérieure a été réalisée au moyen d'une analyse de l'haleine. Le statut tabagique a été comparé et ensuite corrélé avec les taux de CO résultants à un seuil de 6 ppm.

Résultats : La consommation moyenne de cigarettes était de 4,7 par jour ($\pm 1,8$) et le statut tabagique était indiqué pour 19 fumeurs (31,7 %) et 41 non fumeurs (68,3 %) au moment de l'étude. Des corrélations significatives ont été obtenues entre les taux de monoxyde de carbone expiré des groupes fumeurs et non-fumeurs ($p < 0,05$). Indépendamment des mesures du statut tabagique, la fréquence du dépistage des fumeurs était comparable à celle des non-fumeurs ($p = 0,756$).

Conclusions : Comme pour les auto-déclarations, la mesure du CO expiré a réussi à distinguer les fumeurs des non-fumeurs. Cela permet aux prestataires de soins de santé et aux responsables de l'élaboration des politiques d'examiner l'efficacité des programmes de sevrage tabagique et de prévention.

¹ MPOWER = 1) Monitoring tobacco consumption and the effectiveness of preventive measures; 2) Protect people from tobacco smoke; 3) Offer help to quit tobacco use; 4) Warn about the dangers of tobacco; 5) Enforce bans on tobacco advertising, promotion and sponsorship; and 6) Raise taxes on tobacco.

تقييم حالة التدخين: مقارنة التقارير الذاتية بتحليل أول أكسيد الكربون المستنشق بين طلاب جامعيين في جمهورية إيران الإسلامية

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الخلاصة:

الخلفية: يُعتبر التدخين أحد عوامل الخطر الرئيسية لكثير من الأمراض المزمنة والوفيات في جميع أنحاء العالم. ومن ثم، من المهم تحديد عدد المدخنين قبل تنفيذ المبادرات المعنية بمكافحة التبغ. وبسبب الوصم والتدابير الرادعة، أصبح من المستحيل الوصول إلى المدخنين من خلال الاستبيانات ذاتية الإبلاغ.

الأهداف: هدفت هذه الدراسة إلى مقارنة مستويات أول أكسيد الكربون المستنشق بالتقارير الذاتية للطلاب الجامعيين في جمهورية إيران الإسلامية. طرق البحث: شملت هذه الدراسة المقطعية عينة ملائمة ضمت 60 طالباً جامعياً أُسْتُعِين بهم في عام 2016 في طهران. ومن بين هؤلاء الطلاب، كان يوجد 30 امرأة و30 رجلاً وكان متوسط عمرهم 23.1 (±15.6) عاماً. وأجريت مقابلات معهم باستخدام الاستبيان الخاص "بالاتحاد الدولي لمكافحة السل وأمراض الرئة" بعد موافقته، ثم خضعوا للتقييم مرة أخرى عن طريق تحليل النفس. وقد قورنت حالة التدخين، ثم رُبطت بمستويات أول أكسيد الكربون عند حد 6 جزء في المليون.

النتائج: بلغ متوسط استهلاك السجائر 4.7 (±1.8) كل يوم، وأبلغ عن حالة التدخين باعتبار أن 19 شخصاً (31.7%) من المدخنين جالياً، في حين أن نسبة من لم يتعاطوا التبغ بلغت 41 شخصاً (68.3%). وقد تم التوصل إلى العلاقات المهمة بين مستويات أول أكسيد الكربون المستنشق لمجموعات المدخنين وغير المدخنين (القيمة الاحتمالية > 0.05). وبغض النظر عن التدابير الخاصة بحالة التدخين، فإن معدل تواتر المدخنين كان قابلاً للمقارنة مع معدل تواتر غير المدخنين (القيمة الاحتمالية = 0.756).

الاستنتاجات: وعلى غرار التقارير الذاتية، نجح قياس أول أكسيد الكربون المستنشق في تمييز المدخنين عن غير المدخنين. ويتيح ذلك لمقدمي الرعاية الصحية وراسمي السياسات دراسة فعالية البرامج المعنية بالإقلاع عن تعاطي التبغ والوقاية منه.

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