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Halitosis among users of electronic nicotine delivery systems in a multi-center cross-sectional study

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The global utilization of Electronic Nicotine Delivery Systems (ENDS) is increasing, with emerging evidence suggesting a potential link between ENDS and halitosis. Nonetheless, direct data addressing this association remains limited. This study aimed to investigate the effects of ENDS usage on halitosis among individuals aged 18–40 in 18 Middle Eastern and North African (MENA) countries. The study was conducted between November 2023 and May 2024, and employed an online self-administered survey that included the validated Halitosis Finding Score (Halfins). The analysis included a total of 7,973 participants categorized by their smoking habits: 71.1% identified as non-users, 12.6% as ENDS users, 10.8% as traditional tobacco users, and 5.5% as dual users. After adjusting for potential confounders, exclusive ENDS users exhibited significantly greater odds of experiencing halitosis (adjusted odds ratio [AOR] = 1.576, 95% CI = 1.367–1.817, p < 0.001), as did dual users (AOR = 1.420, 95% CI = 1.161–1.738, p < 0.001), than non-users did. These findings suggest that the use of ENDS and dual usage may elevate the risk of developing halitosis. However, due to the limitations of the study, it is important to interpret these results with caution. Nonetheless, reducing the use of ENDS could potentially mitigate the risk of halitosis.

Keywords Electronic nicotine delivery systems, Vaping, Smoking, Halitosis, Cross-sectional studies, Self-Administration

E-cigarettes, also known as electronic nicotine delivery systems (ENDS), have emerged as popular alternatives to traditional tobacco products in recent years due to the claims that they may help with smoking cessation[1,2]. Since 2014, e-cigarette use has increased globally, especially among young people, and e-cigarette use has been the most popular form of smoking among youth[3].

E-cigarette holders usually inhale a nicotine-laden aerosol combined with flavorings and other additions, which is potentially categorized as having such a lower risk than combustible cigarettes[1].

Although e-cigarettes have been highlighted for their rapid increase in use, there are many concerns regarding their health implications and regulatory challenges, such as "halitosis disorder".

Halitosis is a chronic oral malodour condition that may cause personal discomfort and ignominy.

Although halitosis originates in about 80–90% of cases within the oropharyngeal cavity, it might be related to several other non-oral sites. Halitosis occurs when anaerobic bacteria degrade sulfur-containing amino acids to foul-smelling volatile sulfur compounds (VSC). In healthy subjects, halitosis comes from the dorsoposterior surface of the tongue, where the filiform papillae are the favored sites for anaerobic bacteria's growth[4].

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Halitosis can occur in individuals of any age and sex, irrespective of their social status, and may cause profound shame and psychological impact[5]. In general, many people suffer from halitosis. An estimated 31.8% of the general population (95% CI 24.6–39.0%) were found to suffer from halitosis in 2017[5]. However, because there is no universally accepted definition of halitosis, reporting is often subjective, and methodologies vary widely, leading to significant inconsistency in the reported prevalence of halitosis worldwide. Numerous risk factors may be associated with halitosis, such as a person's lifestyle, poor oral hygiene, dental and periodontal diseases, systemic conditions, and dietary habits[6].

Increasing awareness of oral hygiene has led more individuals to seek medical solutions. Despite the popularity of ENDS, there is limited research on its effects on oral health, specifically on conditions such as halitosis[5]. A previous study revealed that ENDS usage is associated with mouth dryness[6]. Another study revealed that ENDS usage led to alteration in composition and type of oral bacteria[7]. Additionally, nicotine in e-liquid can reduce the tone of the lower esophageal sphincter, which can lead to gastroesophageal reflux disease (GERD)[8]. All of these factors are risk factors that lead to halitosis.

Owing to the lack of evidence-based data on the association between ENDS use and halitosis, this cross-sectional study was designed to investigate the potential association between ENDS use and halitosis among Middle East and North African residents. By examining a specific population, we can gain insights into the oral health consequences of ENDS use and their potential importance in halitosis.

Methods

Study design, setting, and participants

We conducted a multinational cross-sectional study across 18 countries in the Middle East and North Africa (MENA) region (Supplementary Table S1). The data collection period was extended from November 20, 2023, to May 25, 2024. A STROBE checklist was used to report the present study (Supplementary Table S2)[9].

The inclusion criteria specified that participants must reside within the MENA region, be aged 18–40, and complete the full survey. We excluded participants who reside outside the MENA region, younger than 18 or older than 40 years, and those who did not complete the survey.

This study complied with the ethical standards of the Declaration of Helsinki[10]. Informed consent was obtained from the interested participants at the beginning of the survey, with the possibility of dropping out of the questionnaire at any point without any consequences. The Research Ethics Committee at the Faculty of Medicine, Benha University (REC-FOMBU) in Egypt granted ethical approval with the registration number 'RC.31.11.2023'.

Data collection tools and procedures

Data were collected via a structured, self-administered Google Form online survey (Supplementary Table S3). The survey was distributed by a team of collaborators through various social media platforms and messaging systems (Facebook, Instagram, Snapchat, Twitter, WhatsApp, Telegram, and email). To ensure the validity of the data and minimize manipulation, the Google Forms tool was configured to permit only one response per participant. Furthermore, the collected data underwent a meticulous review process, during which any suspicious entries—such as incomplete answers or identical response patterns—were excluded from the study.

The survey was composed of three sections. The first section focused on sociodemographic and medical history details and included questions about age, sex, country of residence, and anthropometric measurements for calculating body mass index (BMI), whereas medical history questions covered physical and psychiatric comorbidities, dental problems, and medication or supplement usage, in addition to lifestyle factors include sleep patterns, exercise frequency, average daily water consumption, frequent alcohol consumption, the frequently consumed type of food, and oral hygiene practices.

The second section included questions about the participants' smoking habits, addressing tobacco smoking and ENDS usage status for both current and former smokers.

The final section included the valid Halitosis Finding Score (Halfins). Halfins questionnaire was developed by the Gurpinar study on the basis of a review of the Oral Health Impact Profile (OHIP-14). The final section of this research presents the validated Halitosis Finding Score (Halfins). The Halfins questionnaire, created by Gurpinar, is based on the Oral Health Impact Profile (OHIP-14)[11,12]. It consists of 15 items and uses a Likert scale for assessment. Each item features closed-ended questions with predefined answer options: never (0), rarely (1), often (2), and always (3). The total scores of the questionnaire can range from 0 to 45, with higher scores indicating a greater severity of halitosis. A cutoff point was established, with scores equal or above 14 indicating the presence of halitosis (with a sensitivity of 95.21% and specificity of 85.19%). The original version of the questionnaire was validated among Turkish subjects. To adapt the questionnaire for Arabic speakers, two independent bilingual translators (fluent in both Turkish and Arabic) translated the instrument from Turkish to Arabic. Subsequently, another pair of bilingual translators conducted a backward translation from Arabic to Turkish. The two resulting translations were meticulously reviewed, and discrepancies were resolved.

Sample size calculation

We calculated the sample size via Epi Info version 7.2.5.0 on Microsoft Windows 11. Given the lack of similar studies on halitosis among ENDS users, we based our effect size on a study by Saadaldina et al., which reported a 45% prevalence of halitosis among smokers, a minimum sample size of 570 was calculated to detect a similar effect with a 5% acceptable margin of error, a 1.5 design effect and 95% confidence level[12]. In our study, we utilized a total sample size of 7973 participants. The study included a nonrandomized sample.

Statistical analysis

We utilized the first 100 responses to evaluate the reliability of the Arabic version of the Halfins questionnaire, and the data obtained from this pilot test to assess the reliability of the translated questionnaire were excluded from the final analysis.

Categorical variables are summarized as frequencies and percentages. Continuous variables are presented as means and standard deviations. Data normality was assessed using the Shapiro–Wilk test. Statistical tests included linear model ANOVA for more than two groups, and chi-square tests for categorical data. Multivariable binomial logistic regression models were used to examine the association between product usage status and halitosis. The regression model was adjusted for key confounding factors, including age, sex, dental problems, regular oral hygiene, daily water intake, and frequent alcohol consumption. Analysis was conducted using adjusted odds ratios (AOR), and a confidence interval of 95% (95% CI) was reported. All P values and 95% CI were two-sided and a p-value < 0.05 was considered statistically significant. Participants with missing data were addressed using the MICE (Multiple Imputation by Chained Equations) method. Statistical analysis was conducted using Jamovi, version 2.3.2 (Windows).

Results

Reliability analysis for the translated version of the Halfins questionnaire

Reliability analysis was done to test the reliability of the translated version of Halfins questionnaire, and it yielded a Cronbach's α of 0.9, indicating a high level of internal consistency.

Sample characteristics

In this study, a total of 7973 participants were included in the final analysis and categorized according to their smoking habits. Specifically, 5668 participants (71.1%) identified as non-users, 1003 (12.6%) were exclusive users of ENDS, 859 (10.8%) were traditional tobacco users, and 443 (5.5%) were dual users of both tobacco and ENDS. The mean age of the participants was 24.4 years, with a standard deviation of 4.9 years.

The majority of exclusive ENDS users (81.8%), traditional tobacco users (84.5%), and dual users (88.0%) were male. More than half of the participants, specifically 58.2%, reported engaging in regular physical exercise. Among the different groups, exclusive ENDS users reported the fewest dental problems, with only 33% indicating issues ($p < 0.001$), whereas a greater proportion of non-users practiced regular oral hygiene (75.7%, $p < 0.001$) compared to their counterparts.

Additionally, exclusive ENDS users demonstrated a higher daily water intake, averaging 1.6 L (SD = 0.7), in contrast to non-users, who averaged 1.4 L (SD = 0.7) ($p < 0.001$). Furthermore, a greater percentage of dual users (6.1%) reported frequent alcohol consumption compared to the other groups ($p < 0.001$). Table 1 shows the study distribution of the study group according to their clinical and sociodemographic characteristics.

Associations between halitosis and product use

After adjusting for potential confounders (age, sex, dental problems, regular oral hygiene, daily water intake, and frequent alcohol consumption), exclusive ENDS users exhibited significantly higher odds of experiencing halitosis (adjusted odds ratio [AOR] = 1.576, 95% CI = 1.367–1.817, $p < 0.001$), as did dual users (AOR = 1.420, 95% CI = 1.161–1.738, $p < 0.001$) compared to non-users (Table 2).

Discussion

This multicenter investigation was carried out in the MENA region to evaluate the association between halitosis and nicotine product use (exclusive ENDS use, traditional tobacco use, and dual-use), while the majority of prior investigations have been conducted on tobacco smokers, and only a few studies have been conducted on ENDS[13,14]. This study aimed to provide a comprehensive global picture of the associations between halitosis and the use of different nicotine products, including ENDS, to provide an additional understanding of the safety profile of ENDS.

Our findings revealed that ENDS-only users exhibited a higher likelihood of developing halitosis compared to non-users. A similar trend was observed among dual users of ENDS and traditional tobacco. Interestingly, no significant association was found between exclusive traditional tobacco use and halitosis.

It is hypothesized that propylene glycol (PG) and vegetable glycerine (VG), which are mainly used as solvents in e-cigarette solutions, are hydrophilic, which means that they can bind to and absorb water from saliva, drying out the mouth, also known as xerostomia, which might increase the risk of developing cavities and gum disease[15]. In addition, it may reduce saliva production, which plays a crucial role in neutralizing acidity in the oral cavity and drives out bacteria whose growth can cause malodour breath[16–20]. A recent study conducted by Hasan et al.[21] among adolescents in coffee shops in Baghdad city revealed that vaping devices may contribute to increased feelings of xerostomia. Another meta-analysis by Guo et al.[22] revealed that among dual tobacco and e-cigarette users, the prevalence of xerostomia was 33% (95% CI: 18–48), whereas among tobacco smokers it was only 26% (95% CI: 18–35). E-liquid may also contribute to halitosis through increasing mouth acidity, which can lead to tooth decay and can also create bad breath[23].

E-cigarettes may also alter the balance of the oral microbial community. Saliva has antibacterial effects due to the presence of immunoglobulin A, lysozyme, lactoferrin, histamine, and leukocytes. ENDS products can affect the pH of the oral cavity. The mean salivary pH of e-cigarette users is more acidic than that of nonsmokers, potentially because the compounds in e-cigarette vapor, such as aldehydes, cause a change in the physicochemical antibacterial properties of saliva[19,24,25]. Recent findings by Kim et al.[26] revealed that the use of vegetable glycerin in e-liquids results in a fourfold increase in microbial adhesion to enamel and a twofold increase in biofilm formation, leading to pathogenic bacterial invasion and eventually tooth decay. In addition, the accumulation of

Factors	Non-users (N = 5668)	Exclusive ENDS users (N = 1003)	Tobacco users (N = 859)	Dual users (N = 443)	Total (N = 7973)	p value
Age, Mean (SD)	23.8 (4.7)	25.4 (4.8)	26.7 (5.5)	25.0 (4.5)	24.4 (4.9)	< 0.001[a]
Sex (male)	2650.0 (46.8%)	820.0 (81.8%)	726.0 (84.5%)	390.0 (88.0%)	4586.0 (57.5%)	< 0.001[b]
BMI, Mean (SD)	24.2 (5.4)	25.6 (5.3)	25.0 (5.0)	25.6 (5.8)	24.6 (5.4)	< 0.001[a]
Regular physical exercise (yes)	3307.0 (58.3%)	597.0 (59.5%)	460.0 (53.6%)	280.0 (63.2%)	4644.0 (58.2%)	0.005[b]
Sleep deprivation (yes)	2489.0 (43.9%)	484.0 (48.3%)	452.0 (52.6%)	237.0 (53.5%)	3662.0 (45.9%)	< 0.001[b]
Physical comorbidities (yes)	531.0 (9.4%)	49.0 (4.9%)	82.0 (9.5%)	31.0 (7.0%)	693.0 (8.7%)	< 0.001[b]
Psychiatric comorbidities (yes)	210.0 (3.7%)	30.0 (3.0%)	44.0 (5.1%)	18.0 (4.1%)	302.0 (3.8%)	0.105[b]
Dental problems (yes)	1984.0 (35.0%)	304.0 (30.3%)	342.0 (39.8%)	146.0 (33.0%)	2776.0 (34.8%)	< 0.001[b]
Regular oral hygiene (yes)	4291.0 (75.7%)	680.0 (67.8%)	595.0 (69.3%)	297.0 (67.0%)	5863.0 (73.5%)	< 0.001[b]
Medications/Supplementations use (yes)	540.0 (9.5%)	52.0 (5.2%)	69.0 (8.0%)	23.0 (5.2%)	684.0 (8.6%)	< 0.001[b]
Frequently consumed type of food						
Healthy food	623.0 (11.0%)	79.0 (7.9%)	70.0 (8.1%)	44.0 (9.9%)	816.0 (10.2%)	< 0.001[b]
Dairy products	346.0 (6.1%)	57.0 (5.7%)	49.0 (5.7%)	20.0 (4.5%)	472.0 (5.9%)	
Fatty food	536.0 (9.5%)	169.0 (16.8%)	133.0 (15.5%)	68.0 (15.3%)	906.0 (11.4%)	
No specific food	3231.0 (57.0%)	465.0 (46.4%)	459.0 (53.4%)	221.0 (49.9%)	4376.0 (54.9%)	
Spicy food	498.0 (8.8%)	150.0 (15.0%)	101.0 (11.8%)	65.0 (14.7%)	814.0 (10.2%)	
Sweets	434.0 (7.7%)	83.0 (8.3%)	47.0 (5.5%)	25.0 (5.6%)	589.0 (7.4%)	
Daily water intake, Mean (SD)	1.4 (0.7)	1.6 (0.7)	1.5 (0.7)	1.5 (0.8)	1.4 (0.7)	< 0.001[a]
Caffeinated drinks consumption (yes)	3326.0 (58.7%)	712.0 (71.0%)	616.0 (71.7%)	329.0 (74.3%)	4983.0 (62.5%)	< 0.001[b]
Frequent alcohol consumption (yes)	57.0 (1.0%)	52.0 (5.2%)	29.0 (3.4%)	27.0 (6.1%)	165.0 (2.1%)	< 0.001[b]

Table 1. The study groups' distribution according to clinical and sociodemographic characteristics. ENDS, electronic nicotine delivery system; SD, standard deviation; BMI, body mass index. a. Linear Model ANOVA. b. Pearson's Chi-squared test.

Product use	OR (95% CI)	P-value	AOR* (95% CI)	P-value
Exclusive ENDS use	1.632 (1.426–1.868)	< 0.001	1.576 (1.367–1.817)	< 0.001
Exclusive tobacco smoke	0.983 (0.847–1.142)	0.825	0.894 (0.763–1.047)	0.165
Dual-use	1.507 (1.241–1.831)	< 0.001	1.420 (1.161–1.738)	< 0.001

Table 2. Association between halitosis and exclusive ENDS use, exclusive tobacco use, and dual-use compared to non-users. OR, odds ratio; AOR, adjusted odds ratio; 95% CI, 95% confidence interval; ENDS, electronic nicotine delivery system. *The regression model adjusted for age, sex, dental problems, regular oral hygiene, daily water intake, and frequent alcohol consumption. The reference is the non-user group.

Candida, such as *C. albicans*, can be the cause of oral thrush and can lead to bad breath. A study by Alanazi et al.[27] suggested that e-cigarette vapor promotes *C. albicans* development, whereas exposure of *C. albicans* cultures to NR e-cigarette vapor for 15 min twice a day for 2 days dramatically increased *C. albicans* growth ($p < 0.001$) compared with that of controls.

E-cigarette aerosols may induce oxidative stress, causing cytotoxic effects on oral tissues, dryness, irritation, bacterial infections, and worsening halitosis[28–30].

Another hypothesis is that ENDS have principal components of e-liquids; in turn, they can thermally degrade to form acetaldehyde, acrolein, and formaldehyde, which, when heated in these devices, may affect oral health, causing malodour sensation[31].

Another possible theory is that ENDS use can increase the risk for gastrointestinal reflux disease (GERD), which is linked to halitosis[4,32]. E-liquid nicotine can reduce the tone of the lower oesophageal sphincter tone, which leads to stomach content regurgitation to the esophagus and mouth[8,33]. A cross-sectional-based study conducted by Alturki et al.[34] on a sample of 397 students revealed a higher prevalence of GERD among ENDS users than non-smokers.

Despite the limited research exploring the relationship between halitosis and the use of ENDS, a pilot study conducted by Dalrymple et al.[14] aimed to assess the impact of both traditional tobacco and e-cigarette consumption on breath odor, comparing these groups with non-smokers. However, the findings of this study stand in contrast to our results, suggesting that e-cigarette use does not produce detectable malodour. Nonetheless, the study does exhibit significant limitations. Firstly, the sample size was relatively small, consisting of only 33 participants. Additionally, breath assessments were conducted at a single time point, offering merely a snapshot of breath odor and leaving the long-term effects of e-cigarette use largely unexamined. Furthermore, the selection criteria for participants excluded individuals with alterations in the oral mucosa, gum issues, dental caries, periodontitis, xerostomia, or chronic gastrointestinal conditions such as heartburn. This exclusion may introduce population bias, as it overlooks ENDS users who might experience halitosis due to underlying health issues potentially triggered by ENDS use.

Smoking has been identified as an independent extrinsic contributor to oral halitosis[35]. Several studies have documented a correlation between smoking and self-perceived malodour, particularly when relying on questionnaire data[36]. However, some studies have failed to establish a relationship between smoking and organoleptic measurements of breath odor[37,38]. In our current research, we found no significant association between halitosis and traditional tobacco smoking. This may be attributed to the fact that unpleasant taste in the mouth may influence individuals' perceptions of their own breath odor[39]. While the majority of the literature indicates an increased likelihood of halitosis among tobacco smokers compared with non-smokers, there are notable exceptions. In certain studies, smokers reported a lower prevalence of halitosis than their non-smoking counterparts. For instance, research conducted by Romano et al.[40] found that only 36.1% of the heavy smoker group had self-awareness of oral malodour compared to 54.5% in the non-smoker group, moreover, heavy smokers exhibited a negative correlation between their perception of mouth odor and the results of organoleptic tests (OLT). Similarly, a study by Iwanicka-Grzegorek et al.[37] revealed no significant link between cigarette smoking and halitosis. Additionally, Bornstein et al. found an inverse correlation between cigarette smoking and readings of volatile sulfur compounds (VSCs), with no detectable correlation between smoking and organoleptic assessments[38].

Dual use of tobacco products was significantly correlated with a higher likelihood of experiencing halitosis when compared to non-smokers. Interestingly, the odds of developing halitosis among dual users were found to be lower than those for exclusive electronic nicotine delivery system (ENDS) users. This phenomenon may be attributed to the inconsistency often associated with dual use, making it challenging to determine whether individuals primarily use tobacco or ENDS. Furthermore, many tobacco smokers may adopt dual use as a strategy to gradually reduce their tobacco consumption[41].

Our study possesses several notable strengths. Firstly, it utilized a large and diverse sample representing populations from 18 countries within the MENA region (supplementary table 1), an area frequently underrepresented in existing research. Secondly, our regression analysis included key variables identified in previous studies, i.e., age, sex, and frequent alcohol consumption, thereby reducing the impact of confounding factors. Lastly, we employed the validated Halfins questionnaire to collect data on halitosis, ensuring the reliability and accuracy of our measurements.

Although our cross-sectional study provides valuable insights into halitosis among different groups – non-users, tobacco users, ENDS users, and dual users—it's important to acknowledge key limitations that might impact our results' interpretations. Firstly, study design was cross-sectional, which restricts our ability to determine causal relationships or the temporal sequence of events. However, observational studies are the only applicable design due to ethical considerations of conducting clinical trials and asking participants to smoke. It is important to mention that both product use, and halitosis questionnaires were self-reported, which introduces the possibility of self-reporting bias and recall bias, and may affect the accuracy of reported outcomes. While we use a valid questionnaire to diagnose halitosis, this stool is still subjective and not objective. Although the survey was reported anonymously, due to the sensitivity of the questions, social desirability bias is still possible. Additionally, smokers may underreport halitosis due to their perceiving smoking breath, not halitosis, or because of the unpleasant taste in the mouth, which may influence individuals' perceptions of their own breath odor.[39] Finally, our reliance on convenience sampling may limit the generalizability of the findings due to potential selection bias, and due to the questionnaire being published on social media platforms, we were unable to calculate the response rate. These methods, while necessary for recruiting a large and diverse population across the MENA region, do not guarantee a fully representative sample. To mitigate this limitation, we ensured anonymity, confidentiality, and voluntary participation, which encouraged broader involvement. The large sample size also helps reduce the impact of potential bias, enhancing the study's robustness. Future research should consider incorporating longitudinal and experimental designs to explore the underlying mechanisms and mediating effects of product use on these relationships, further improving the generalizability and depth of understanding.

In conclusion, this study revealed that exclusive ENDS users and dual users have a higher likelihood of developing halitosis compared to non-smokers. Interestingly, this link was not found in people who consume exclusive conventional tobacco. This suggests that the compounds and mechanisms involved in ENDS and

dual use may contribute uniquely to oral health issues such as bad breath, which could be caused by factors such as altered saliva production, changes in oral microbiota, oxidative stress, or specific chemical exposures associated with ENDS. Although these findings should be interpreted with caution due to the study limitations, it is recommended that individuals avoid the use of ENDS and dual use to mitigate the risk of halitosis.

Data availability

The data supporting this study's findings are available from the corresponding author upon reasonable request.

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SMS, AS, WA, MR, MMA contributed to the study's conceptualization. SMS contributed to the methodology and validation. WA, SMS, and OH contributed to data curation. SMS conducted the formal analysis. SMS, MR, MMA, and WA wrote the original draft. All authors contributed to reviewing and editing the manuscript. AS and SMS coordinated the data collection process, AMT, BGM, AMAO, MAA, AAH, AA, RNS, MUA, and ASM contributed to data collection. NAH supervised the study. DARS contributed to data collection for this study.

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Competing interests

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Additional information

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