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The effect of heated-cigarette smoking on voice in comparison to combustion-cigarette smoking: self-perceived evaluation

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Main Article

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Abstract

Objective. To investigate the effect of heated-cigarette smoking on voice.
Methods. Participants completed a survey including three sections: section-1 comprised demographic data, section-2 comprised visual analogue scale grading of voice changes and fatigue and section-3 consisted of the voice handicap index-10.
Results. Two hundred and eighty-two participants filled the survey. Heated-cigarette smokers had a significantly higher mean voice handicap index-10 score compared to non-smokers ($p < 0.05$). The difference in voice handicap index-10 scores between heated- and combustion-cigarette smokers was not statistically significant. The number of abnormal voice handicap index-10 scores was higher in heated-cigarette smokers compared to non-smokers ($p < 0.05$) and significantly higher in combustion-cigarette and dual heated- and combustion-cigarette smokers compared to the other 2 groups ($p < 0.05$). Non-smokers had significantly lower grades of voice changes and fatigue when compared to combustion and dual heated- and combustion-cigarette smokers ($p < 0.05$).
Conclusion. Smokers of heated cigarettes have a significantly higher mean voice handicap index-10 score compared to non-smokers and higher grade of voice changes and fatigue.

Introduction

Smoking is recognised for its adverse effects on health causing preventable-disease disabilities.[1] The toxic components of cigarette combustion have a multifaceted and detrimental effect on the immune system and cellular growth via genomic and non-genomic pathways, leading to unbridled cell proliferation and the inception of cancer. Smoking also instigates the accumulation of atherosclerotic plaques within arterial walls and contributes to lipid dysregulation by elevating triglyceride levels and diminishing high-density lipoprotein (HDL) cholesterol. All the above act in concert to augment the risk of cardiovascular events and strokes, among other diseases.[2,3]

The effect of smoking on phonation has gained significant attention over the last few decades. All three components of the phonatory apparatus are affected by smoking. The adverse effect is not limited to the vocal folds but extends to include the resonators in addition to the power supply. In a study that included 3600 adults, Byeon *et al.* reported that smokers had 1.8 times higher risk for self-reported voice problems than non-smokers.[4] These findings concur with numerous studies showing a strong association between smoking and structural disorders of the upper airway, particularly the vocal folds.[5,6]

The adverse effect of combustion-cigarette smoking on voice is mostly ascribed to the combustion process. This has led to the inception of 'safer' smoking products such as heated cigarettes. Heated cigarettes were first developed in the1980s and have gained popularity as a safer alternative to combustion cigarettes due to their heat-not-burn mechanism.[7] The heat-produced aerosol is less concentrated in tobacco-specific nitrosamines (7–17 times lower), nicotine, carbonyl and tar in comparison to combustion-produced aerosol. Additionally, reactive oxygen species are 40–60 times and 1.5–8 times lower in heated cigarettes compared to combustion cigarettes, respectively[7].

Since the introduction of heated cigarettes, there has been a growing prevalence of their usage, particularly among individuals trying to quit smoking and limit second-hand smoke exposure. Epidemiological data showed that heated cigarettes are mainly used in the younger population who never smoked, and very often in combination with other products. The Population Assessment of Tobacco and Health study reported that 37.4 per cent of adults and 43 per cent of youths who smoke used multiple nicotine products.[8]

The effect of heated-cigarette smoking on voice has scarcely been investigated in the literature. In a cross-sectional study that included 81 participants, Tuhanioğlu *et al.* reported a higher mean voice handicap index-10 score in conventional smokers in

comparison to e-cigarette smokers and controls.[9] However, there was no significant difference in the fundamental frequency and perturbation parameters, jitter and shimmer percentage, among the three subgroups. The authors concluded that e-cigarettes had a milder subjective effect on voice in comparison to conventional cigarettes.[9] In another animal study, Salturk *et al.* investigated the effect of electronic cigarettes on the laryngeal mucosa of rats ($n = 8$) following 4 weeks of vapor exposure. They reported two cases of hyperplasia and four cases of metaplasia.[10] There was no significant difference in the prevalence of mucosal changes in the study group in comparison to controls. The authors noted the need for future studies with more-prolonged exposure to e-cigarette vapor to decide on the long-term effect of e-cigarette smoking.[10]

Given the scarcity of reports on the effect of heated-cigarette smoking on voice, the authors of this manuscript were intrigued to further investigate the self-perceived voice changes in heated-cigarette smokers. Understanding the effect of heated-cigarette smoking on voice is essential in the work-up of patients with dysphonia as vocal hygiene therapy is integral in the management of affected patients. The objective of this study is to examine the effect of heated-cigarette smoking on voice using self-reported questionnaires. The authors also aim to compare the effect of heated-cigarette smoking on voice to the effect of combustion-cigarette smoking.

Material and methods

Subjects and settings

This study is an observational, descriptive cross-sectional study conducted at a single tertiary care centre using emailed surveys. All participants were adults aged 18 years and above. All those who had history of a recent upper respiratory infection or history of laryngeal manipulation within the last 30 days prior to receiving the survey were excluded. All participants completed a survey that consisted of three sections. Section one comprised demographic data such as age, gender, profession (professional voice users *vs* non-professional voice users based on whether the participant relied on their voice to make a living), type of cigarette smoked, duration of smoking, number of cigarettes smoked, and presence or absence of history of reflux disease and allergy. Section two comprised patient-reported grading of voice change and voice fatigue using the visual analogue scale (VAS) of 1–10, with 10 being the worst grading score. Section three consisted of the voice handicap index-10, which is a self-reported questionnaire on the effect of dysphonia on quality of life.[11]

Participation was voluntary and restricted to survey responders. Institution-Review Board approval and informed consent from the participants were secured (SBS-2023-0040).

Statistical analysis

The data were analysed using the Statistical Package for the Social Sciences (SPSS, version 27; IBM Corporation, Armonk, NY, USA). Descriptive statistics of the data were translated into mean and standard deviation or frequency and percentages. The distribution of the variables was measured by the Kolmogorov–Smirnov test. The chi-square test as well as the Kruskal–Wallis, and Mann–Whitney U tests were used in the analysis of independent data. The significance value of 0.05 was used to interpret the results ($p < 0.05$ was considered statistically significant).

Results

Demographic data

Two hundred and eighty-two participants completed the survey and were included in this study. There were 181 females (64.1 per cent) and 101 males (35.9 per cent). The age of participants was recorded as intervals. Ninety-eight patients (34.8 per cent) were 18–25 years old, 96 (34 per cent) were 26–40 years old, and 88 (31.2 per cent) were above the age of 41 years.

The participants were divided into four groups: group A, non-smokers ($n = 131$); group B, combustion-cigarette smokers ($n = 52$); group C, heated-cigarette smokers ($n = 64$); and group D, dual heated- and combustion-cigarette smokers ($n = 35$). The overall prevalence of history of allergy within the study population was 32.6 per cent and that of reflux disease was 29.8 per cent. There was a total of 34 (12 per cent) professional voice users (Table 1).

Using the chi-square test, both age ($X^2(6) = 15.62$, $p = 0.016$) and gender ($X^2(3) = 13.62$, $p = 0.003$) were found to be possible confounders for the type of cigarettes used. Heated-cigarette smokers were more likely to be male and 26–40 years old. Non-smokers were mostly females more than 40 years old. Combustion-cigarette smokers and dual heated- and combustion-cigarette smokers were mostly males. Dual heated- and combustion-cigarette smokers were predominantly young (18–25 years old). Further analysis accounted for both factors.

Most smokers had been smoking for at least a year (> 50 per cent) with the highest portion (29 per cent) having smoked for 2–5 years. For the number of cigarettes smoked, heated-cigarette smokers were more likely to be heavy smokers, a third of them (33.9 per cent) smoking 10–20 cigarettes per day, and more than 75 per cent being daily smokers (> 1 cigarette per day). Combustion-cigarette smokers and dual heated- and combustion-cigarette smokers mostly smoked 1–5 cigarettes per month or week (> 50 per cent) (Appendix A).

All analyses accounted for both the number of cigarettes smoked and the total duration of smoking.

Voice change and voice fatigue grading using the VAS in all groups

The mean grade of voice change in group A was 1.46. The mean grade of voice changes in groups B, C and D were 2.19, 1.88 and 2.63, respectively. The mean grade of voice fatigue in group A was 1.71. The mean voice fatigue grades in groups B, C and D were 2.83, 2.45 and 2.91, respectively (Table 2).

A Kruskal–Wallis test showed that at there was a significant difference of means in both voice-change grade and voice-fatigue grade among the four groups ($H(3) = 23.48$, $p < 0.001$). Heated-cigarette smokers had higher grade of voice change and voice fatigue than non-smokers; however, the difference was not statistically significant ($p > 0.05$). Post-hoc tests for pairwise comparisons also showed that non-smokers had significantly lower grades than patients in groups B or D ($p < 0.05$). Results were consistent when adjusted for age, gender, duration of smoking and the number of cigarettes smoked.

Voice handicap index-10 scores in all groups

The mean voice handicap index-10 score in group A was 2.64. The mean voice handicap index-10 scores in groups B, C and D were 7.06, 4.67 and 9, respectively (Table 2).

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Table 1. Demographics table showing number of patient and respective percentages for age, sex, allergy status, and reflux disease

	Non-smokers (Group A)	Combustion cigarette smokers (Group B)	Heated cigarette smokers (Group C)	Combustion + heated cigarette smokers (Group D)	Total
Age (years)					
18–25	42	15	24	17	98
26–40	36	20	28	12	96
≥ 41	53	17	12	6	88
Sex (F:M)	99:32	25:27	39:25	18:17	181:101
Positive history of allergy	43 (32.8%)	18 (34.6%)	19 (29.7%)	12 (34.3%)	92 (32.6%) $P = 0.94$
Positive history of reflux	37 (28.2%)	15 (28.8%)	23 (35.9%)	9 (25.7%)	84 (29.8%) $P = 0.66$
Professional voice users	17 (13%)	6 (11.5%)	8 (12.5%)	3 (8.6%)	34 (12%) $P = 0.91$
Total	131	52	64	35	282

Table 2. Voice outcome measures; VAS = visual analogue scale; VHI-10 = voice handicap index-10

	Non-smokers (Group A)	Combustion cigarette smokers (Group B)	Heated cigarette smokers (Group C)	Combustion + heated cigarette smokers (Group D)
Voice quality grade (VAS score)	1.46 ± 0.94	2.19 ± 1.55	1.88 ± 1.45	2.63 ± 1.91
Voice fatigue grade (VAS score)	1.71 ± 1.45	2.83 ± 1.99	2.45 ± 2.15	2.91 ± 2.29
VHI-10 score	2.64 ± 3.2	7.06 ± 6.01	4.67 ± 4.72	9.00 ± 6.95

A Kruskal–Wallis test showed that at there was a significant difference of means for the voice handicap index-10 scores among the four groups ($H(3) = 46.71$, $p < 0.001$) (Fig. 1). Post-hoc tests of pairwise comparisons showed that non-smokers had a significantly lower mean voice handicap index-10 score than smokers, including heated-cigarette smokers which had a significantly higher score than non-smokers ($p < 0.05$). Heated-cigarette smokers had a lower mean voice handicap index-10 score than dual heated- and combustion-cigarette smokers ($p = 0.02$). There was no significant difference in mean voice handicap index-10 scores between heated-cigarette and combustion-cigarette smokers ($p = 0.22$), or between combustion-cigarette smokers and dual heated- and combustion-cigarette smokers ($p = 1.0$). Results were consistent when adjusted for age, gender, duration of smoking and number of cigarettes smoked.

- Smoking is recognized for its adverse effects on health causing preventable-disease disabilities
- Understanding the effect of heated-cigarette smoking on voice is essential in the work-up of patients with dysphonia
- Heated-cigarette smokers had higher voice handicap index-10 scores compared to non-smokers
- Non-smokers had lower grades of voice changes in comparison to combustion and dual heated- and combustion-cigarette smokers
- The effect of heated-cigarette smoking on voice is milder than that of combustion-cigarette smoking

The number of abnormal voice handicap index-10 scores (i.e. > 11) was significantly higher in groups B and D compared to groups A and C ($p < 0.05$). The number of patients with abnormal voice handicap index-10 was higher in heated-cigarette smokers than non-smokers, however results did not reach statistical significance.

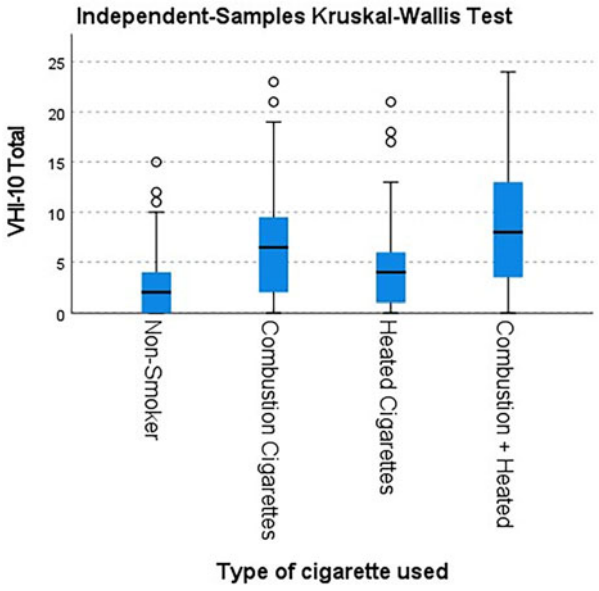

Figure 1. Box plots of Kruskal–Wallis statistics for VHI-10 (voice handicap index-10) total values for the four patient populations in this study based on type of cigarette used.

Discussion

The results of this investigation indicate that heated-cigarette smokers had a significantly higher mean voice handicap index-10 score and a higher prevalence of abnormal voice handicap index-10 score (> 11) in comparison to non-smokers. The results also support that participants who smoke heated cigarettes had higher grade of voice change and higher grade of voice fatigue than non-smokers, even though the difference between the two groups did not reach

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statistical significance. Notably, the prevalence of abnormal voice handicap index-10 score (> 11) was lower in heated-cigarette smokers in comparison to combustion-cigarette smokers, but not significantly lower.

The results of this investigation agree with those of Tuhanioğlu *et al.* who also reported a lower mean voice handicap index-10 score in e-cigarette smokers in comparison to conventional cigarette smokers. The authors also noted a higher mean voice handicap index-10 score in conventional smokers compared to e-cigarette smokers and non-smokers.[9]

It is well established that combustion-cigarette smoking affects voice. The results of this investigation showed that heated-cigarette smoking also affects voice and can significantly affect quality of life. This can be attributed to many factors, the most important of which is mucosal inflammation. It is well established that the compounds in combustion cigarettes linked to laryngeal inflammatory changes are also found in heated cigarettes, albeit in smaller concentrations. Although heated-cigarette smoking is void of aromatic amines, hydrogen cyanide and polycyclic aromatic hydrocarbons,[12] heated cigarettes still contains the chemical compounds released from combustion cigarettes that are linked to mucosal inflammation, namely tobacco-specific nitrosamines, tar, carbon monoxide, and reactive oxygen species, but in lower concentrations.[13] To that end, heated cigarettes might exacerbate voice changes by inducing structural changes via inflammatory and non-inflammatory mediators.[14] This assumption remains hypothetical given the lack of laryngeal examination in the participants of our study.

Another cause for the significantly higher mean voice handicap index-10 score and higher grade of voice change and fatigue in heated-cigarette smokers compared to non-smokers is mucosal desiccation, given the known drying effect of heated-cigarette smoking on the mucosal lining of the oropharyngeal lining. In a study on nicotine delivery of heated cigarettes as an alternative to combustion cigarettes, Yingst *et al.* noted mouth dryness and throat irritation in three out of eight participants.[15] The participants in their study were combustion-cigarette smokers trying to quit by switching to heated cigarettes. In another cross-sectional telephone survey of 4964 US adults, dry or irritated mouth/throat was reported in 31.0 per cent of the combustion-cigarette smokers.[16] Dehydration, local or systemic, is inversely related to phonatory effort and phonatory threshold pressure, which is the pressure needed to set the vocal folds into vibration. Laryngeal desiccation can lead to increase in phonatory effort and vocal fatigue with subsequent change in voice quality. To that end, mucosal dryness secondary to heated-cigarette smoking may be partially responsible for the high grade of vocal fatigue and higher voice handicap index-10 score in subjects who smoke heated cigarettes in comparison to non-smokers.

Another potential cause for the higher prevalence of abnormal voice handicap index-10 scores in heated cigarettes smokers compared to non-smokers is the known adverse effect of heated-cigarette smoking on the lower airway. Many studies have shown that heated-cigarette smoking causes cellular, functional and molecular changes in human bronchial epithelial cells.[6] Albeit lower than combustion cigarettes, heated cigarettes still have been shown to induce changes in bronchial cells with long-term exposure that could eventually lead to atypia.[17] Heated-cigarette smoking has been linked to cytotoxicity at the bronchial level, with marked inflammatory dysregulations involving interleukin-1 beta and interleukin-6. The toxicity profile was still lower than that linked to combustion-cigarette smoke exposure.[18]

Another important finding in our study is that dual heated- and combustion-cigarette smokers had the highest mean voice handicap index-10 scores and highest subjective grading for voice change and voice fatigue. In fact, a Korean study on 7550 adults showed that dual heated- and combustion-cigarette smokers had greater nicotine dependence and higher levels of urinary cotinine (metabolite of nicotine) when compared to combustion-cigarette smokers.[19] These findings allude to a synergistic and/or cumulative effect of smoking in patients who smoke more than one type of tobacco.[7] We could speculate that this added effect is related to the toxic compounds found exclusively in heated cigarettes as well as the cumulative delivery of particles already found in combustion cigarettes and known to cause harm.

Another potential adverse effect of heated cigarettes if misused is the excessive heat which may be harmful to the vocal folds. Lechien *et al.* reported a 55-year-old female who presented with persistent dysphonia and throat pain following the use of e-cigarettes without filling the water chamber. The dysphonia was attributed to vocal fold mucosal injury and ulceration that was treated with behavioural dietary modification and anti-reflux medication.[20]

The primary limitations of the present study are the monocentric design and the lack of objective voice quality assessment, including acoustics, aerodynamics or videolaryngostroboscopy. Another limitation, inherent to the nature of this study, is the lack of data on confounding factors such as allergy and reflux disease which may mask or exacerbate oropharyngeal and laryngeal symptoms.

Conclusion

There is still a gap in the literature on the effect of heated-cigarette smoking on voice. The results of this investigation indicate that subjects who smoke heated cigarettes have significantly higher voice handicap index-10 scores in comparison to non-smokers. They also had a higher grade of voice change and fatigue compared to non-smokers, although the difference was not statistically significant. The effect of heated-cigarette smoking on voice was found to be milder than that of combustion-cigarette smoking. Further research based on laryngeal findings and using objective acoustic and/or aerodynamic measurements is needed. Large comparative studies of heated cigarettes, combustion cigarettes and e-cigarettes are also lacking.

Author contributions. All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Christophe Abi Zeid Daou, Yara Yammine and Ibana Carapiperis. The first draft of the manuscript was written by Abdul-Latif Hamdan, Christophe Abi Zeid Daou and Vanessa Helou. Christopher Jabbour facilitated implementation and institutional research board approval. Jerome Lechien, Justin Ghadieh and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Declaration of interest. The authors report there are no competing interests to declare.

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