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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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Abstract

Objective: To investigate the effect of heated-cigarette smoking on voice.

Methods: Participants filled a survey including three sections; section-1 comprised demographic data, section-2 comprised visual analog scale (VAS) grading of voice changes and fatigue and section-3 consisted of the voice handicap index-10 (VHI-10).

Results: Two hundred and eighty-two participants filled the survey. Heated-cigarette smokers had a significantly higher mean VHI-10 score compared to non-smokers ($p<0.05$). The difference in VHI-10 scores between heated and combustion cigarette smokers was not statistically significant. The number of abnormal VHI-10 scores, was higher in heated-cigarette smokers compared to non-smokers ($p<0.05$) and significantly higher in combustion-cigarette and dual 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 smokers ($p<0.05$).

Conclusion: Smokers of heated-cigarettes have a significantly higher mean VHI-10 score compared to non-smokers and higher grade of voice changes and fatigue.

Keywords: dysphonia, voice handicap index, cigarette, smoking, heated cigarettes, combustion, cigarettes, otolaryngology, voice.

Introduction

Smoking is recognized for its adverse effects on health causing preventable disease-disabilities[1]. The toxic components of cigarette combustion exert a multifaceted and detrimental impact 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 impact 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 3,600 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 (CC) smoking on voice is mostly ascribed to the combustion process. This has led to the inception of "safer" smoking products such as the heated cigarettes (HC). Heated cigarettes (HC) were first developed in the1980s and have gained

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popularity as a safer alternative to combustion cigarettes due to their heat-not-burn mechanism[7]. The heat-produced aerosol is less concentrated in TSNA (7-17 times lower), nicotine, carbonyl and tar in comparison to combustion-produced aerosol. Additionally, reactive oxygen species (ROS) are 40-60 times and 1.5-8 times lower in HC compared to CC, respectively[7]. Since the introduction of HC, 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 HC 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% of adults and 43% of youths who smoke used multiple nicotine products[8].

The effect of HC smoking on voice has scarcely been investigated in the literature. In a cross-sectional study which included 81 participants, *Tuhanioglu et al* reported a higher mean VHI-10 score in conventional smokers in comparison to e-cigarette smokers and controls. However, there was no significant difference in the fundamental frequency and perturbation parameters, jitter and shimmer percentage, between 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 and reported 2 cases of hyperplasia and 4 cases of metaplasia. 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 HC smoking on voice, the authors of this manuscript were intrigued to further investigate the self-perceived voice changes in HC smokers.

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Understanding the impact of HC 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 HC smoking on voice using self-reported questionnaires. The authors also aim at comparing the effect of HC smoking on voice to that of CS smoking.

Material and Methods

Subjects and settings

The study is an observational, descriptive cross-sectional study conducted at a single tertiary care center 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 filled 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 the fact that he or she relied on his or her voice to make a living), type of cigarette smoked, duration of smoking, amount of cigarete 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 analog scale (VAS) of 1 to 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 impact of dysphonia on quality of life[11].

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

Statistical analysis

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The data were analyzed using the IBM Statistical Package for the Social Sciences (SPSS) Version 27.0 package program (IBM Corp., Armonk, N.Y., 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 test 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 filled the survey and were included in this study. There were 181 females (64.1%) and 101 males (35.9%). The age of participants was recorded as intervals. Ninety-eight patients (34.8%) were between 18 and 25 years, 96 (34%) were between 26 and 40 years, and 88 (31.2) were above the age of 41 years.

The participants were divided into four groups: group A, non-smokers (n=131), group B, CC smokers (n =52), group C, HC smokers (n =64), and group D, dual HC and CC smokers (DS, n=35). The overall prevalence of history of allergy within the study population was 32.6% and that of reflux disease was 29.8%. There was a total of 34 (12%) 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. HC smokers were more likely to be male and aged between 26-40 years. Non-smokers were mostly females

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older than 40 years. Combustion cigarette smokers and DS were mostly males. DS were predominantly young, aged 18-25. Further analysis accounted for both factors.

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

All analysis 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 grade 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 between the four groups ($H(3)=23.48$, $p <0.001$). Heated Cigarettes smokers had higher grade of voice change and voice fatigue than non-smokers, however, the difference was not statistically significan ($p > 0.05$). Post-hoc tests to test 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 amount of cigarettes smoked.

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VHI-10 scores in all groups

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

A Kruskal-Wallis test showed that at there was a significant difference of means of the VHI-10 scores between the four groups ($H(3)=46.71$, $p<0.001$) (Fig 1). Post-hoc tests to test pairwise comparisons showed that non-smokers had a significantly lower mean VHI-10 score than smokers, including HC smokers which had significantly higher score than non-smokers ($p<0.05$). Also, HC smokers had a lower mean VHI-10 score than DS ($p=0.02$). There was no significant difference in mean VHI-10 scores between HC and CC smokers ($p=0.22$), and between CC smokers and DS smokers ($p=1.0$). Results were consistent when adjusted for age, gender, duration of smoking and amount of cigarettes smoked.

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

Discussion

~~The impact of HC smoking on voice was never investigated.~~ The results of this investigation indicate that HC smokers had a significantly higher mean VHI-10 score and a higher prevalence of abnormal VHI-10 score (above 11) in comparison to non-smokers. The results also support that participants who smoke HC 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 statistical significance. Notably, the prevalence of abnormal VHI-10 score,

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i.e. above 11, was lower in HC smokers in comparison to CC smokers, but not significantly lower. The results of this investigation are in agreement with those of *Tuanioglu et al* who also reported lower mean VHI-10 score in e-cigarette smokers in comparison to conventional cigarette smokers. The authors also noted a higher mean VHI-10 score in conventional smokers compared to e-cigarette smokers and non-smokers[9].

It is well established that CC smoking affects voice. The results of this investigation showed that HC smoking also affects voice and can significantly impact quality of life. This can be attributed to many factors most important of which is mucosal inflammation. It is well-established that the compounds in CC linked to laryngeal inflammatory chnages are also found in HC, albeit in smaller concentrations. Although HC smoking is void of aromatic amines, hydrogen cyanide and polycyclic aromatic hydrocarbons[12], it still contains the chemical compounds released from CC that are linked to mucosal inflammation, namely TSNA, tar, carbon monoxide, ROS, but in a lower concentration[13]. To that end, HC 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 VHI-10 score and higher grade of voice change and fatigue in HC smokers compared to non-smokers is mucosal desiccation given the known drying effect of HC smoking on the mucosal lining of the oropharyngeal lining. In a study on nicotine delivery of HC as an alternative to CC, *Yingst et al* noted mouth dryness and throat irritation in 3 out of 8 participants[15]. The participants in their study were CC smokers trying to quit by switching to HC. In another cross-sectional telephone survey of 4,964 American adults, dry or irritated mouth/ throat was reported in 31.0% of the CC smokers[16]. Dehydration, local or

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systemic, is inversely related to phonatory effort and phonatory threshold pressure, that 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 HC smoking may be partially responsible for the high grade of vocal fatigue and higher VHI-10 score in subjects who smoke HC in comparison to non-smokers. Another potential cause for the higher prevalence of abnormal VHI-10 scores in HC smokers compared to non-smokers is the known adverse effect of HC smoking on the lower airway. Many studies showed that HC smoking causes cellular, functional and molecular changes in human bronchial epithelial cells[6]. Albeit lower than CC, HC are still 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 IL-1B and IL-6. The toxicity profile was still lower than that linked to CC smoke exposure[18].

Another important finding in our study is that DS smokers had the highest mean VHI-10 scores and highest subjective grading for voice change and voice fatigue. In fact, a Korean study on 7,550 adults showed that DS had greater nicotine dependence and higher levels of urinary cotinine (metabolite of nicotine) when compared to CC smokers[19]. These findings allude to a synergistic/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 HC as well as the cumulative delivery of particles already found in CC and known to cause harm. Another potential adverse effect of HC if misused is the excessive heat which may be harmful to the vocal folds. Lechien JR et al reported a 55-year-old female who presented with persistent dysphonia and throat pain following the use of e-cigarette without filling the water

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chamber. The dysphonia was attributed to vocal fold mucosal injury and ulceration that wass treated with behavioral 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 HC smoking on voice. The results of this investigation indicate that subjects who smoke HC have significantly higher VHI-10 score 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 HC smoking on voice was found to be milder than that of CC smoking. Further research based on laryngeal findings and using objective acoustic/aerodynamic measurements are needed. Large comparative studies between HC, CC and e-cigarettes are also lacking.

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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, implementation and IRB approval. Jerome Lechien, Justin Ghadieh and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declaration of interest

The authors report there are no competing interests to declare.

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Ethical Approval

This study was approved by the Institutional Review Board of the American University of Beirut Medical Center, Lebanon. IRB ID: SBS-2023-0040

Tables

Table 1. Demographics table showing number of patient and respective percentages for age, sex, allergy status, reflux disease and VHI-10 scores.

	Non-Smokers (Group A)	Combustion Cigarette Smokers (Group B)	Heated Cigarettes Smokers (Group C)	Combustion + Heated cigarettes 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

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Table 2. Voice outcome measures

	Non-Smokers (Group A)	Combustion Cigarette Smokers (Group B)	Heated Cigarettes Smokers (Group C)	Combustion + Heated cigarettes 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

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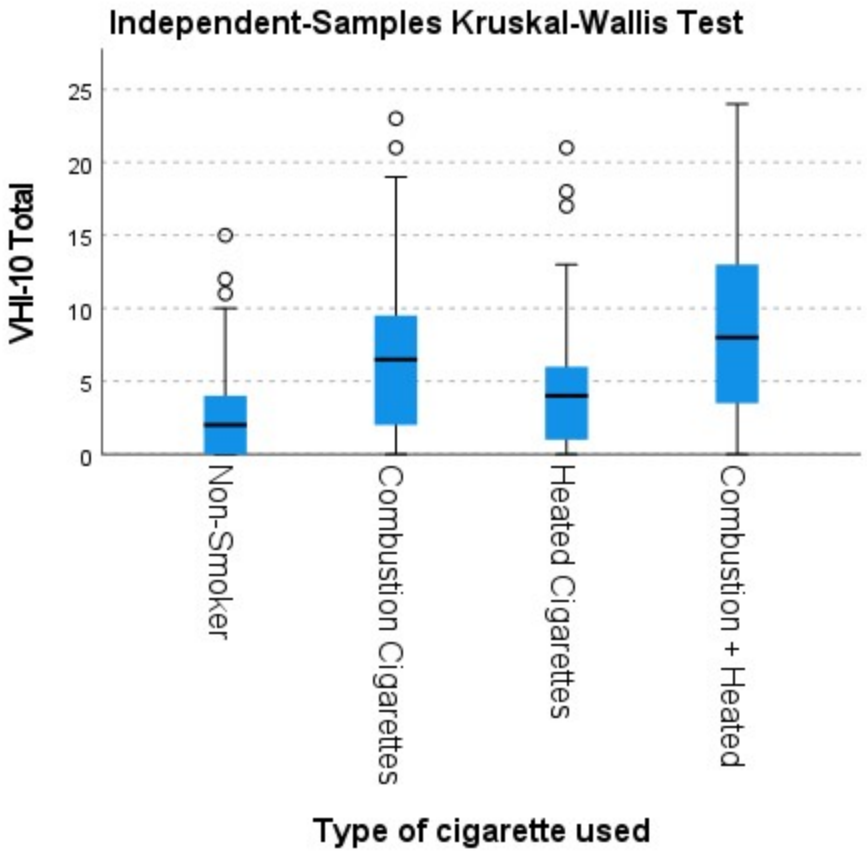

Figure 1

Summary

- Smoking is recognized for its adverse effects on health causing preventable disease-disabilities.
- Understanding the impact of heated cigarette (HC) smoking on voice is essential in the work-up of patients with dysphonia.
- HC 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 smokers.
- The effect of HC smoking on voice is milder than that of combustion cigarette smoking.

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