The Effect of Electronic Cigarettes on Voice Quality

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Summary: Objectives. Cigarette-associated diseases have frequently been detected in the field of otolaryngology. Cigarettes can cause changes in voice performance. The aim of the present study was to investigate the effect of e-cigarettes on voice performance compared with conventional cigarettes.

Materials and Methods. This is a cross-sectional study that included 81 healthy volunteers. To provide standardization, all patients were men. The patients were divided into three groups: e-cigarette users (group 1, n = 21), conventional cigarette users (group 2, n = 30), and nonsmokers who had never smoked (group 3, n = 30). The subjective and objective voice analyses were performed for all the three groups in the study. F0, jitter %, shimmer %, shimmer dB, harmonics-to-noise ratio (HNR) values, and Voice Handicap Index 10 were statistically compared between all groups.

Results. The mean Voice Handicap Index 10 values of the conventional cigarette users were higher than those of the e-cigarette users and control group. No significant difference regarding the F0, jitter, and shimmer percentage values between the groups was detected; however, a significant difference was detected regarding the shimmer dB and HNR values between the groups. The mean shimmer dB values of the conventional cigarette group were higher than those of the control group and electronic cigarette users, but the mean HNR values were lower than those of the control group and electronic cigarette users.

Conclusions. The effects of e-cigarettes on voice were detected as mild compared with conventional cigarettes, according to the subjective and objective voice analysis results in our study.

Key Words: Electronic cigarette–Acoustics–Objective voice analysis–Voice Handicap Index–Smoking.

INTRODUCTION

Cigarette-associated diseases have frequently been detected in the field of otolaryngology. In particular, smoking cigarettes causes high risks of larynx diseases, such as vocal polyps, vocal carcinomas, chronic inflammation, Reinke edema, and laryngeal mucosal irritation.[1–3] In addition, researchers in various studies in the literature suggest that cigarettes cause changes in the fundamental frequency (F0), jitter, and shimmer in evaluating the aerodynamics, acoustic, and perceptual performance of voice.[4–6]

In recent years, the use of electronic cigarettes (e-cigarettes) has become prevalent among people who are giving up smoking. e-Cigarettes were first developed in China in 2003[7] and contain propylene glycol, glycerol, distilled water, flavorings, and nicotine.[8] Propylene glycol and glycerol are involved in many food and pharmacologic preparations and are approved products by the Food and Drug Administration.[9] The nicotine content may vary between 0 and 34 mg/mL.[10] Although the presence of toxins in the liquid and vapor of e-cigarette was confirmed in a study, subsequent studies emphasized that the toxins were 9- to 450-fold less than in conventional cigarettes.[11] The possible effect of e-cigarettes on the larynx was expected to be mild due to the lower amount of toxins[12]; however, the effect of e-cigarettes on voice characteristics has not been investigated in previous studies. The present study aimed to investigate the effect of e-cigarettes on voice performance compared with conventional cigarettes.

MATERIALS AND METHODS

Study population

The present study was conducted at the Adana City Hospital in the otolaryngology clinic with 81 volunteers. All of them were working at the same hospital like us, and they were examined in the voice department. The age of the volunteers was between 18 and 54 years, and to provide standardization, all volunteers selected were men. The volunteers were divided into three groups: e-cigarette users (group 1, n = 21), conventional cigarette users (group 2, n = 30), and nonsmokers who had never smoked (group 3, n = 30). All men in group 1 used to smoke conventional cigarettes; however, the inclusion criterion is that all men had to have used e-cigarettes for 1–3 years. The nicotine content of the e-cigarettes was 9 and 12 mg/mL and these smokers inhale 1–2 mL/d. This nicotine range was near the amount in the conventional cigarettes to avoid the effect of nicotine dose differences on the results. Group 2 consisted of men who smoked 10–20 conventional cigarettes per day and had done so for 1–5 years. These volunteers were selected because they used approximately the same nicotine dose and cigarette brand as those in group 1. Volunteers in groups 1 and 2 were selected who were using 10–20 mg of nicotine per day. Group 3 comprised men with no history of smoking.

The oral cavity and nasal cavity, nasopharynx, and larynx were examined in all participants. Patients excluded from the study include those with a history of infection,

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septum deviation, allergic rhinitis, reflux laryngitis, asthma, oropharynx, and nasopharynx lesions. Those with a history of laryngeal intubation within the last 3 months, and especially patients with a larynx pathology (eg, polyp, nodule, and Reinke edema), were also excluded from the study. Additionally, the professional voice users were excluded because of the deterioration effects of voice analysis. In addition, volunteers who used less than 10 mg and more than 20 mg nicotine daily were excluded. We researched 120 volunteers initially, but we continued with 81 men because of the exclusion criteria. Ethics board approval (2017/73) and informed consent from the participants were obtained. The subjective and objective voice analyses were performed for all the three groups in the study.

Subjective voice analysis

The Turkish version of the Voice Handicap Index 10 (VHI-10) scale was performed on the participants to evaluate voice symptoms, which were evaluated between 0 and 4. The scores increased as the voice symptoms increased.[13] The VHI-10 was compared between the groups.

Objective voice analysis

The Paul Boersma and David Weenink voice analysis system (*Praat*) is one of the leading voice analysis programs. All participants were seated in a quiet room, and analysis was done from voice samples collected through a 20-cm high-quality dynamic microphone (Audio Technica at 2020) connected to a computer.

Voice samples were elicited by asking each participant to produce sustained phonations of the /a/ sound at their habitual levels of pitch and loudness. The investigator ensured that each participant was comfortable and competent in producing sustained phonations at their habitual levels. Three sustained phonations (with each phonation lasting longer than 3 seconds) were then recorded. The second production was used for data analysis.

To rule the out effects of onset and offset voicing, the segment analyzed was a 1-s portion in the middle of the vowel production. The selected segments were later digitized (50-kHz sampling rate) and analyzed using the *Praat*, and we chose five of the *Praat* acoustic parameters of voice. The other *Praat* parameters were excluded as irrelevant for the experiment's purposes. The fundamental frequency F0, jitter %, shimmer %, shimmer dB, and harmonics-to-noise ratio (HNR) were measured on acoustic voice analysis. F0, jitter %, shimmer %, shimmer dB, HNR values, and VHI-10 were statistically compared between all groups.

Statistical analysis

The mean and standard deviation were used in the descriptive statistics of the data. The distribution of the variables was measured by the Kolmogorov-Smirnov test. The one-way ANOVA (analysis of variance) with *post hoc* Tukey HSD (honestly significant difference) test, Kruskal-Wallis, and Mann-Whitney *U* test were used in the analysis of quantitative independent data. The chi-square test was used for the analysis of qualitative independent data, and the Fisher exact test was used when chi-square test conditions were not supplied. The data were analyzed using the IBM *Statistical Package for the Social Sciences (SPSS)* Version 22.0 package program (Armonk, NY). The significance value of 0.05 was used to interpret the results; $P < 0.05$ was considered statistically significant.

RESULTS

The study consisted of 81 volunteer individuals who were divided into three groups: group 1 consisted of 21 (26.9%) men who were smoking e-cigarettes, group 2 consisted of 30 (37%) men who had smoked for at least 1 year and the number of cigarettes smoked daily was 10−20, and group 3 (control group) consisted of 30 (37%) healthy men. The mean age was 35.99 years (standard deviation ± 7.797) and ranged from 18 to 54 years.

The mean VHI-10 values of the conventional cigarette users were higher than those of the e-cigarette users and the control group ($P < 0.05$) (Table 1).

TABLE 1.
Comparison of Objective and Subjective Acoustic Parameters

		Conventional Cigarette Users		Electronic Cigarette Users		Control Group		
		Mean ± SD/n (%)	Median	Mean ± SD/n (%)	Median	Mean ± SD/n (%)	Median	*P*
Age		35.8 ± 6.2	35.5	37.3 ± 8.6	39.0	35.2 ± 8.7	36.0	0.745†
Mean Pitsch F0		138.7 ± 23.8	132.8	153.6 ± 30.7	154.7	141.1 ± 16.6	138.7	0.192†
Jitter %		0.31 ± 0.14	0.29	0.26 ± 0.18	0.16	0.26 ± 0.07	0.25	0.052†
Shimmer %		3.81 ± 2.71	2.86	2.60 ± 0.95	2.63	2.67 ± 0.83	2.76	0.269†
Shimmer dB		0.34 ± 0.24	0.25	0.22 ± 0.08§	0.23	0.22 ± 0.16§	0.17	0.011†
HNR (dB)		20.4 ± 4.0	20.9	23.3 ± 4.2§	24.2	22.9 ± 2.7§	23.3	0.007*
VHI-10	0	23 (76.7%)		20 (95.2%)§		29 (96.7%)§		0.027‡
	I	6 (20.0%)		1 (4.8%)		1 (3.3%)		
	II	1 (3.3%)		0 (0.0%)		0 (0.0%)		

* ANOVA (Tukey test).
† Kruskal-Wallis (Mann-Whitney U test).
‡ Chi-square test.
§ Difference with conventional cigarette user group, $P < 0.05$.
Abbreviation: SD, standard deviation.

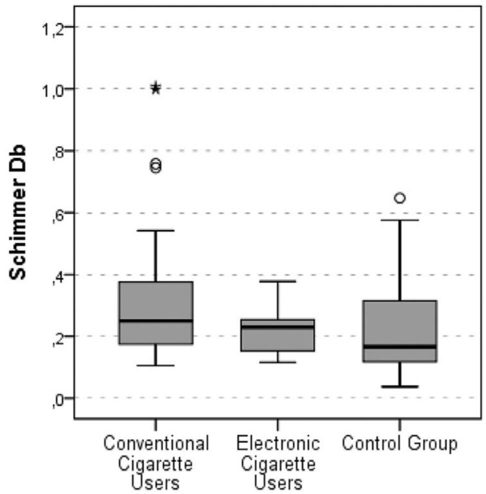

FIGURE 1. Comparison of shimmer dB in three groups.

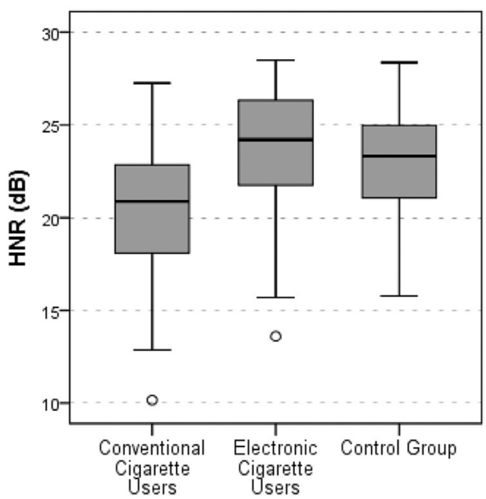

FIGURE 2. Comparison of HNR in three groups.

No significant difference regarding the F0, jitter %, and shimmer % values between the groups was detected; however, a significant difference was detected regarding the shimmer dB and HNR values between the groups (Table 1). The mean shimmer dB values of the conventional cigarette group were higher than those of the control group and electronic cigarette users, and a significant difference was detected between the conventional cigarette users, electronic cigarette users, and control group ($P < 0.05$) (Figure 1). A significant difference in HNR values was also detected between the conventional cigarette users, e-cigarette users, and control group ($P < 0.05$). The mean HNR values of e-cigarette users and control group were higher than those of the conventional cigarette users (Figure 2).

DISCUSSION

The aim of the present study was to evaluate the effects of e-cigarettes on voice parameters and to compare these results with those of conventional cigarette smokers. We detected lower VHI-10 values for e-cigarette users compared with conventional cigarette users in the present study. The objective values showed that many parameters were affected; however, significant differences were detected only in shimmer dB and HNR values.

VHI-10 is a simplified questionnaire used in the subjective evaluation of voice analysis and might be used as a guide in the early detection of voice diseases. Although previous studies investigating the effects of cigarettes on voice reported that cigarettes caused significant changes on VHI-10, some studies reported that cigarettes caused no changes. In their study with female patients, Tafiadis et al found that the VHI-10 total score was significantly higher in cigarette users.[6] However, Glas et al found results suggesting no difference in their comparative study of VHI-10 between smokers and nonsmokers.[14] We found that VHI-10 values are significantly lower in e-cigarette users; thus, the voice quality was higher in these participants.

The objective voice analysis is a noninvasive, easy-to-perform test that may be comfortably used to monitor the effects of diseases on voice. F0, jitter %, shimmer %, and HNR measurements in voice analysis are important in identifying the acoustic characteristics of voice. Many studies in the literature investigated the effects of conventional cigarettes on voice, but the research on the effects of e-cigarettes is insufficient.

Jitter and shimmer are the two common perturbation measures in acoustic analysis. These two measurements are used to verify the perturbation level in the voice signal, and they are modestly correlated with voice quality characteristics such as hoarseness or roughness.[15] Jitter and shimmer indicate the frequency and amplitude variation from one successive cycle to the next and thus can be used as a measure of frequency and amplitude instabilities.[16] In the literature, researchers demonstrated how the use of cigarettes affected voice quality due to edema in the vocal cord epithelium, increased wheezing and breathlessness, and increased shimmer by reducing glottic resistance.[17] In their study with smoking and nonsmoking adult men, Chai et al found that the jitter and shimmer percentage values were significantly higher in the smoking group.[4] Researchers in another study investigating women who smoked detected the shimmer and jitter percentage values significantly higher per the acoustic analysis results.[6] However, the authors of other studies concluded that cigarettes had no association with acoustic voice changes in contrast to studies that detected that cigarettes caused changes per objective voice analysis results.[18,19]

In our study, jitter %, shimmer %, and shimmer dB were detected to be higher in the conventional cigarette smoking group. However, significant difference was observed only in shimmer dB values, and there was no significant difference in jitter % and shimmer % values. F0 is defined as the number of vocal fold vibratory cycles per second[20] and is utilized for the comparison between intrasubject and intersubject pitch levels. It is expected that F0 would be sensitive to structural and physiological changes in the vocal fold tension, and the cross-sectional mass suggested that the changes in F0 or loudness reflected a loading response by the laryngeal muscles as was expected to occur after a period of prolonged talking.[20,21] In the previous studies, it was demonstrated that F0 was decreased with smoking.[6,22] In our study, we concluded that F0 was higher in the e-cigarette group compared with the conventional cigarette group but significance was not observed.

An increase in HNR in periodic portions of speech was said to reflect a more efficient function of vocal fold vibration and articulatory setting with subcortical stimulation.[23] Our results presented that HNR was increased significantly in the e-cigarette group, which is in line with the literature.[6]

The use of e-cigarettes has become prevalent in recent times as an alternative to avoid the harmful effects of conventional cigarettes[8]; however, the potential consequences of using e-cigarettes have not yet been clarified. We found no studies investigating their effects on the voice using the objective voice analysis. The acoustic characteristics of the voice might be less affected in the e-cigarette group because increased secretion affects the acoustic characteristics of the voice in the smoking group. Therefore, secretion in e-cigarette users might be observed low compared with the conventional cigarette users. Despite the lack of adequate studies, this might also be due to the lower toxin content and higher vapor content of e-cigarettes compared with conventional cigarettes. However, because e-cigarettes are perceived as a new popular method for giving up smoking, more comprehensive studies must be conducted on e-cigarettes and their effects on voice.

In their experimental study, Regina et al investigated the histology and the detrimental effects of conventional cigarettes on the larynx and demonstrated that the ducts in the neighboring cells were deepened in the vocal cord surface epithelium.[24] Their study showed that cigarettes had detrimental effects on the respiratory epithelium.[24] In addition, cigarettes may cause inflammation, acanthosis, hyperkeratosis, dysplasia, leukoplakia, erythroplakia, and carcinoma.[25] Therefore, the increase of secretion and the need for clearing the throat and coughing after the damage results in irritation and edema by increasing vocal cord trauma; thus, it may affect acoustic analyses with deterioration of the vocal cord vibration.

The effects of e-cigarettes on the larynx were investigated in an experimental study with rats exposed to e-cigarettes for 1 hour daily for 1 month, and insignificant metaplasia and hyperplasia were detected in the larynx of the rats.[12] This study, which examined the laryngeal histopathologic changes caused by e-cigarette use, revealed no significant epithelial changes in the e-cigarette group, and epithelial changes up to squamous cell carcinoma were observed in classic cigarette smoking studies.[25] In our study, e-cigarettes were correlated with milder objective and subjective sound changes than were with conventional cigarettes.

The main limitation of our study was that although we selected the individuals in the groups with a standardized nicotine dose, other product contents in classic and e-cigarettes might have varied. Because few people use e-cigarette, it will be favorable to compose studies with the same e-cigarette brand in larger populations. In addition, the alterations in the voice of volunteers over time were not analyzed because our study was cross sectional, and it could have been significantly strengthened with these data.

CONCLUSIONS

The effects of e-cigarettes on voice were detected as mild compared conventional cigarettes, according to the subjective and objective voice analysis results in our study. We find there is a need for more studies in this regard.

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All procedures performed in this study involving human participants were per the ethical standards of the institutional and national research committee as well as the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The ethics committee of the Adana Numune Training and Research Hospital provided ethical approval. The ethical approval number is ANEAH EK.2017/73.

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