Effects of Daily Electronic Cigarette Use on the Vocal Mechanism: A Multimodality Investigation

*Cora Ling, M.Sc., +Victoria McKenna, Ph.D., ~Andres Llico, Ph.D., *Rita Patel, Ph.D.
*Dept. of Speech, Language and Hearing Sciences, Indiana University
+Dept. of Communication Sciences and Disorders, University of Cincinnati
~ Dept. of Biomedical Engineering, University of Cincinnati

INTRODUCTION

- Electronic cigarettes (e-cigarette) produce aerosol by heating a liquid that contain propylene glycol, glycerin, nicotine and other harmful substances;[1] to deliver nicotine and other flavors to the lungs; and are often considered as a safer alternative to tobacco smoking.
- A rise of e-cigarette use in adults and adolescence have been observed. In 2020, 3.7% of adults in the USA reported current use of e-cigarettes.[2] Approximately 2.06 million middle and high school students in the USA reported current use of e-cigarettes in 2021.[3]
- Limited exposure of 1-16 weeks of e-cigarette vapor has been reported to result in mucosal inflammation to animal vocal folds tissues and engineered vocal fold mucosal structure.[4,5,6]
- Several studies have demonstrated the adverse effects of airway inflammation,[7] and increased airway resistance[8] from e-cigarette exposure in the pulmonary literature. However, there are limited studies investigating the detrimental effects of chronic e-cigarette use on the laryngeal and upper airway function.
- A scoping review[9] of 32 studies reported side-effects from e-cigarettes of cough, mouth/throat irritation, dry mouth/throat, or sore throat in 17 studies. One study described a harsh voice quality with e-cigarette use.
- Tuhanioglu et al (2019)[10] found e-cigarette users (1-3 years) to have lower VHI-10 and shimmer (dB) compared to conventional cigarette users. An unpublished thesis[11] found e-cigarette users (>1 year) to have raised shimmer (%) as well as significant difference in mucosal wave, free edge, phase closure, vocal fold varices and vocal fold edema.
- Most studies investigated single modality and only one study with a small sample size (n = 7)[11] evaluated the effect of e-cigarette on vocal fold vibration. The current study extends previous studies to evaluate the impact of e-cigarettes on voice and respiration in multiple modalities.

OBJECTIVE

- To characterize vocal fold vibratory and respiratory function in individuals who do and do not use e-cigarettes.

METHODS

Participants

- Daily/primary e-cigarette users for at least 3 months, n = 25 (IU = 21 , UC = 4)
  - Male, n= 10, mean age = 20.8 (18-27 years); Female, n =15, mean age = 23.1 (18-33 years)

Table 1: Profile of individuals who vape

	Male	Female
Duration of use	Mean = 3.39 (2-5 years)	Mean = 2.53 (0.42 – 6 years)
# of puffs per day	Mean = 53.88 puffs (5-200 puffs)	Mean = 62.27 (10-200 puffs)
Conventional cigarette use	Current conventional cigarette user: n = 2 • 1 cig/day, n = 1; occasionally, n = 1 Prior conventional cigarette user: n= 2 • 1cig/week, n = 1; 1 cig/day, n = 1	Current conventional cigarette user: n = 0 Prior conventional cigarette user: n= 4 • 1cig./day, n = 2 • 2 cigs./ month, n =1 • 0 cigs./ day, n = 1

- Control group, n = 31 (IU = 20 , UC = 11)
  - Male, n=10, mean age = 24.7 (21-29 years); Female, n=21, mean age = 23 (18-36 years)

METHODS

Instrumental evaluation

- **Outcome Measurements on voice and breathing**
  - Voice Handicap Index (VHI)[12]
  - Vocal Fatigue Index (VFI)[13]
  - University of Cincinnati Dyspnea Questionnaire (UCD)[14]
  - Modified Medical Research Council Dyspnea Scale (MMRC)[15]
- **Glottal aerodynamics (Phonatory Aerodynamic System, PentaxMedical #6600)**
  - Vital capacity (liters) from maximum exhalation after maximum inhalation
  - Subglottal pressure (cmH_2O) from three sets of 5 repetitions of /pi/
- **Simultaneous High-Speed Videoendoscopy (HSV) & audio for vocal fold vibrations**
  - Habitual pitch and loudness recorded at 4000Hz (video) & 44kHz (audio) during sustained vowel /i:/ and laryngeal diadochokinetic task of repeated /hi.hi.hi/
- **Respiratory kinematics during speech**
  - Respiratory kinematics recorded at 4000Hz during rest breathing and 2nd sentence of Rainbow Passage[16]

Data Analysis

- Glottis Analysis Tool: Segmentation and analysis using 100 cycles from the midportion of the sustained vowel /i:/ of high-speed video recordings were conducted to obtain the glottal area waveform[17]
- Custom Matlab software: Angular closing velocity (degree/s), maximum abductory angle (degree) and kinematic stiffness[18] (velocity/angle) were obtained from /hi.hi.hi/
- Lung volume initiation, lung volume termination, total lung excursion and airflow were determined for the 2nd sentence of the rainbow passage[19]

RESULTS

Statistical Analysis

- Two-way ANOVA showed main effect of gender for UCD physical (p = .04) and UCD total (p = .03), vital capacity (p < .01), and amplitude quotient (p <.01). No significant differences between e-cigarette users and controls.

Table 2: Mean and standard deviations of outcome measurements

		VHI	UCD				VFI			MMRC
		Total	Physical	Speech	Physical + Speech	Total	Tiredness	Physical discomfort	Improvement	Total
E- cig user	Male	10.70 ± 7.59	18.40 ± 2.41	12.30 ± 2.31	19.20 ± 2.10	49.90 ± 5.55	5.60 ± 5.62	1.50 ± 2.80	4.70 ± 4.06	0.40 ± 0.52
	Female	9.86 ± 10.97	21.80 ± 6.39	12.80 ± 5.31	23.47 ± 6.14	58.07 ± 14.68	3.93 ± 4.65	1.00 ± 1.51	3.40 ± 4.32	0.73 ± 0.46
Controls	Male	6.11 ± 3.72	17.00 ± 3.62	12.10 ± 2.73	16.70 ± 4.19	45.80 ± 8.04	6.20 ± 7.47	0.70 ± 0.82	5.90 ± 3.41	0.30 ± 0.48
	Female	6.11 ± 5.27	18.62 ± 3.32	12.14 ± 1.56	20.86 ± 4.32	51.62 ± 8.26	3.71 ± 3.85	1.05 ± 1.75	3.43 ± 4.27	0.43 ± 0.51

Table 3: Mean and standard deviation of glottal aerodynamic and respiratory kinematic measurements

		Max. Exhalation	/pi.pi.pi.pi.pi/			2nd sentence of Rainbow Passage	
		Vital capacity (L)	Subglottal pressure (cmH_2O)	Vocal frequency (Hz)	Sound pressure level (dB)	Lung volume initiation (%)	Lung volume termination (%)
E-cig user	Male	5.33 ± 1.18	4.77 ± 1.75	156.49 ± 58.99	76.63 ± 8.99	10.71 ± 5.00	-1.49 ± 2.99
	Female	3.74 ± 0.68	5.70 ± 1.50	195.34 ± 37.28	80.74 ± 3.91	15.54 ± 10.69	3.22 ± 8.09
Controls	Male	5.17 ± 0.88	5.70 ± 2.85	189.57 ± 70.48	66.34 ± 1.93	10.67 ± 8.63	0.64 ± 4.12
	Female	3.96 ± 1.02	5.54 ± 2.50	192.91 ± 46.94	77.83 ± 5.60	9.00 ± 4.51	-1.01 ± 3.81

Table 4: Mean and standard deviation of vocal frequency and intensity for sustained phonation during HSV

		Fundamental frequency (Hz)	Sound pressure level (dB) @ 30cm
E-cig user	Male	152.69 ± 48.88	76.83 ± 6.20
	Female	244.31 ± 47.06	77.18 ± 10.03
Controls	Male	128.24 ± 40.49	77.90 ± 10.39
	Female	236.67 ± 43.08	76.27 ± 8.50

RESULTS

Figure 1: Vocal fold kinematic measures derived from HSV during /hi.hi.hi/ task

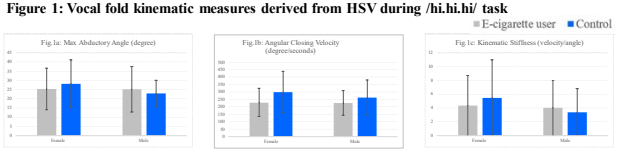
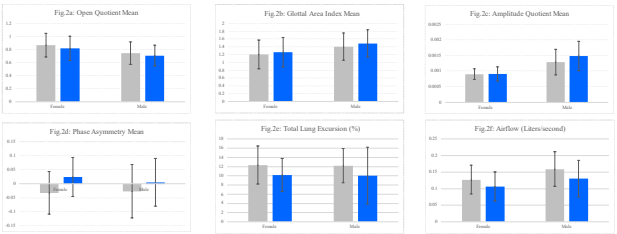


Figure 2: Vocal fold kinematic measures derived from HSV during sustained /i/ (2a,b,c,d) & respiratory kinematic during speech (2e,f)



DISCUSSION

- Expected differences in voice outcome measures, respiration and high-speed data were not observed
  - Future studies will need to evaluate long term effects of e-cigarette use on voice and respiration in young healthy participants
- The e-cigarette users exhibited a lower angular closing velocity, glottal area index, amplitude quotient and phase asymmetry, as well as a higher airflow and total lung excursion although the differences were not statistically significant
  - These vocal fold kinematic trends could be attributed to increased inflammation of the vocal folds due to e-cigarette use

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