Objective and Subjective Evaluation of Larynx in Smokers and Nonsmokers: A Comparative Study

Hansa Banjara · Varsha Mungutwar ·
Digvijay Singh · Anuj Gupta

Received: 25 February 2011 / Accepted: 9 November 2011 / Published online: 30 November 2011
© Association of Otolaryngologists of India 2011

Abstract The deleterious effects of smoking on laryngeal mucosa are indisputable. Smoking not only causes histologic (microscopic) alterations in the vocal fold epithelium but also affect the acoustic property of voice. The goal of this study was to determine the effects of smoking on the laryngeal structures and phonatory physiology via videostroboscopy, acoustic voice analysis and electroglottography. Cross-sectional and observational study was carried out in Department of ENT, Pt. J. N. M. Medical College, Raipur, in 100 male volunteers (50 smokers and 50 nonsmokers) between the ages of 18 and 60 years with no voice complaints. All subjects were analyzed for detailed history and underwent videostroboscopic, acoustic voice analysis and electroglottographic examination. Videostroboscopic examination results showed significant relationships between smoking and abnormal vocal fold edge, abnormal texture, edema, erythema, abnormal mucosal cover, abnormal phase symmetry and abnormal pliability/stiffness. Voice analysis showed that smoking has a clear effect on some acoustic voice and electroglottographic parameters. The parameters most commonly affected by smoking are fundamental frequency (F0), jitter, shimmer, F0 tremor, normalized noise energy, signal noise ratio, maximum phonation time (MPT), s/z ratio, opening rate and closing rate. The results indicate that smoking has a significant effect on laryngeal structures and phonatory physiology.

Keywords Videostroboscopy · Acoustic analysis · Electroglottography · Smoking

Introduction

The detrimental effects of smoking on human health are widely known. In particular, specific morphologic changes within the larynx have been shown to occur with smoking. Myerson [1] described chronic inflammatory changes in the larynx caused by smoking and called this group of symptoms *smoker's larynx*. Smoking is well known to have effects on the characteristics of the voice. The commonly observed characteristics of the smoking voice are changes in fundamental frequency characteristics. It may be expected that the acoustic and electroglottographic (EGG) differences reported for the smoking voice may reflect underlying differences in the structure and function of the laryngeal mechanism.

Numerous studies have been conducted to observe the effects of smoking on the laryngeal structures of smokers. However, specific observations determined via detailed subjective and objective evaluation (videostroboscopic evaluation, acoustic voice analysis and electroglottography) of smoker's laryngeal anatomy and physiology has the potential to provide greater insight to functional aspect of *smoker's larynx*.

Aims and Objectives

1. Effects of smoking on the laryngeal structures using videostroboscopy.
2. Comparative study of larynx by videostroboscopy between smokers and nonsmokers.

H. Banjara · V. Mungutwar · D. Singh · A. Gupta
Department of ENT & Head Neck Surgery, Pt. Jawaharlal Nehru
Memorial Medical College, Raipur, Chhattisgarh, India

D. Singh (✉)
Sr. MIG-17, Sector-4, Pt Deendayal Upadhyay Nagar,
Raipur 492010, Chhattisgarh, India
e-mail: drdiggi@yahoo.com

3. Comparative study of acoustic analysis of voice between smokers and nonsmokers.
4. Comparative study of EGG assessment of voice between smokers and nonsmokers.

Materials and Methods

The study was carried out in the Department of ENT, Pt. J. N. M. Medical College, Raipur and Dr. B. R. A. M. Hospital, Raipur (C.G.) during the period of May 2008–May 2010 on 100 subjects.

Inclusion Criteria

1. 50 Smokers and 50 nonsmokers male subject between the age of 18 and 60 years with no voice complaints were selected.
2. Smoker was defined as any subject who, at the time of this study, had smoked at least two cigarettes per day for at least 1 year.
3. Nonsmoker was those who, at the time of this study, did not smoke and who had not smoked for at least 5 years before the study.

Exclusion Criteria

Subject with any voice complaint, uncooperative or not willing for examination and excessive gag reflex, history of chronic cough or gastroesophageal reflux disease or history of any significant laryngeal trauma were excluded from study.

Videostroboscopic Examination

Videostroboscopic examinations were conducted using a 70-degree rigid endoscope connected to a Karl Storz strobe unit. Stroboscopic videos and images were recorded. For evaluation of videostroboscopic recordings, three otolaryngologists served as judges.

The rating form used by the judges was adapted from videostroboscopic rating forms described by Hirano Bless and Stemple et al. [2, 3]. Various parameters rated for each videostroboscopic image are shown in Table 1. A criterion level of at least two judge agreements was set for accepting the videostroboscopic rating for each parameter. The parameter that failed to reach this level of agreement were not used for final evaluation and mentioned as “cancelled”.

Acoustic Voice Analysis and Electroglottographic Examination

Acoustic voice analysis and EGG measures were done using Electroglottograph (Tiger DRS) in a room with a noise level below 40 dB and the output signals were displayed and analyzed by a computerized software package (Dr. Speech Vocal Assessment).

The acoustic voice parameters evaluated were fundamental frequency (F0), frequency perturbation, amplitude perturbation, F0 tremor, normalized noise energy (NNE), harmonic-noise ratio (HNR), signal-noise ratio (SNR), amplitude tremor, maximum phonation time (MPT) and S/Z ratio. The EGG parameters evaluated were fundamental frequency (EGG-F0), EGG-Jitter, EGG-Shimmer, EGG F0 tremor, EGG NNE, EGG HNR, EGG SNR, EGG amplitude tremor, contact quotient (CQ), contact index (CI), CQ perturbation, CI perturbation, opening rate and closing rate.

Method of Statistical Analysis

All statistical analysis was conducted using the SPSS v. 10.0 statistical software package (SPSS Corporation, Chicago, IL) [4]. For the analysis of categorical measures, a series of Chi-square (χ^2) procedures were conducted. The findings of each videostroboscopic parameters in smokers and nonsmokers group were analysed by χ^2 to know the significance value. Level of significance used in calculation was 0.05 and 0.01. For the comparative analysis of quantitative data, Student's *t*-test (for independent samples) was applied. The mean values of each acoustic voice analysis and EGG parameters in smokers and nonsmokers group were analysed by *t*-test to know the significance value. Level of significance used in calculation was 0.05.

Observation and Results

A total of 100 male subjects (50 smokers and 50 nonsmokers) free of any voice complaints presented to the ENT outpatient department, Pt. J. N. M. Medical College and associated Dr. B. R. A. M. Hospital, Raipur from May 2008 till May 2010 were included in this study. Age of subjects ranged between 18 and 60 years.

Results and observation further grouped under following headings

- I. Various laryngeal characteristics (parameters) determined by videostroboscopy for nonsmokers and smokers.

Table 1 Rating form used for evaluation of videostroboscopic recordings

S.No.	Parameters	Rating						
1.	Vocal fold edge							
	Right	0-Straight	1-Bowed	2-Swollen	3-Irregular	4-Cannot rate		
	Left	0-Straight	1-Bowed	2-Swollen	3-Irregular	4-Cannot rate		
2.	Texture							
	Right	0-Smooth	1-Mild rough	2-Moderate rough	3-Severe rough	4-Cannot rate		
	Left	0-Smooth	1-Mild rough	2-Moderate rough	3-Severe rough	4-Cannot rate		
3.	Mucosal cover							
	Right	0-Thin	1-Normal	2-Thick	3-Cannot rate			
	Left	0-Thin	0-Thin	2-Thick	3-Cannot rate			
4.	Edema							
	Right	0-Normal	1-Mild/Moderate	2-Severe				
	Left	0-Normal	1-Mild/Moderate	2-Severe				
5.	Phase symmetry	0-Regular	1-50% asymmetrical	2-75% asymmetrical	3-Cannot rate			
6.	Pliability/Stiffness							
	Right	0-Normal/Pliable	1-Mild stiffness	2-Moderate stiffness	3-Severe stiffness	4-Cannot rate		
	Left	0-Normal/Pliable	1-Mild stiffness	2-Moderate stiffness	3-Severe Stiffness	4-Cannot rate		
7.	Vocal fold mobility							
	Right	0-Normal	1-Paresis	2-Paralysis	3-Cannot rate			
	Left	0-Normal	1-Paresis	2-Paralysis	3-Cannot rate			
8.	Size of glottal gap	0-No glottal gap	1-Mild glottal gap	2-Moderate glottal gap	3-Severe glottal gap	4-Cannot rate		
9.	Diagram best representing glottal closure pattern	0-Complete	1-Anterior	2-Posterior	3-Spindle	4-Hourglass	5-Irregular	6-Incomplete 7-Cannot rate
10.	Erythema	0-None	1-Mild	2-Moderate	3-Severe			
11.	Ventricular fold compression							
	Right	0-Normal	1-Slightly compressed	2-Moderately compressed	3-Fully compressed	4-Cannot rate		
	Left	0-Normal	1-Slightly compressed	2-Moderately compressed	3-Fully compressed	4-Cannot rate		
12.	Organized lesion(s)	1. Yes	2. No					
		If yes, mention it _____						

AGE DISTRIBUTION AMONG SMOKERS AND NON SMOKERS

Fig. 1 Age distribution among smokers and nonsmokers

- II. Observation of acoustic voice parameters among nonsmokers and smokers.
- III. Observation of EGG parameters among nonsmokers and smokers.

Age Distribution

Age distribution among nonsmokers and smokers were shown in Fig. 1. The age of subjects ranged between 18 and 60 years. Mean age of nonsmokers and smokers were 37.22 ± 10.07 and 37.80 ± 11.52 years respectively. Maximum subjects (59%) were in third and fourth decade of life. Nonsmokers showed higher percentage in third decade (34%) followed by fifth decade (24%) of life; while smokers showed higher percentage in fourth decade (36%) followed by third decade (26%) of life.

Comparison of Various Videostroboscopic Parameters Among Smokers and Nonsmokers

These are shown in Table 2. In present study, 12 laryngeal characteristics (parameters) determined by videostroboscopy were observed and rated by three otolaryngologists for male smokers and non-smokers (50 each). Some parameters differed between smokers and non-smokers, which can be attributed as consequence of smoking.

Abnormal vocal fold edge ($\chi^2 = 10.47$), texture ($\chi^2 = 20.25$), edema ($\chi^2 = 10.51$) and erythema ($\chi^2 = 27.01$) shows statistically highly significant relationship in smokers as compared to nonsmokers group (significant at $P < 0.01$). Abnormal mucosal cover ($\chi^2 = 6.30$), phase symmetry ($\chi^2 = 5.18$) and pliability/stiffness ($\chi^2 = 5.97$) showed statistically significant relationship in smokers as compared to nonsmokers group (significant at $P < 0.05$). While statistically no significant relationship was observed for vocal fold mobility, glottal gap size, glottal closure pattern, ventricular fold compression and organized lesions between smokers and nonsmokers.

Observation of Acoustic Voice Analysis Among Smokers and Nonsmokers

Mean of acoustic parameters with standard deviation are shown in Table 3. 10 acoustic voice parameters were observed in non-dysphonic adult male smokers and non-smokers (50 each) using computerized software package (Dr. Speech Vocal Assessment). Some acoustic parameters differed between smokers and non-smokers, which can be attributed as consequence of histological changes caused by tobacco.

Table 2 Comparison of various videostroboscopic parameters among nonsmokers and smokers

S. No	Rated characteristic	Nonsmokers		Smokers		χ^2
		Normal	Abnormal	Normal	Abnormal	
1.	Vocal fold edge	46 (93.9%)	3 (6.1%)	32 (68.1%)	15 (31.9%)	10.47**
2.	Texture	49 (98%)	1 (2%)	31 (62%)	19 (38%)	20.25**
3.	Mucosal cover	39 (84.8%)	7 (15.2%)	29 (61.7%)	18 (38.3%)	6.30*
4.	Edema	42 (84%)	8 (16%)	27 (54%)	23 (46%)	10.51**
5.	Phase symmetry	48 (98%)	1 (2%)	40 (85.1%)	7 (14.9%)	5.18*
6.	Pliability/stiffness	39 (81.2%)	9 (18.8%)	28 (58.3%)	20 (41.7%)	5.97*
7.	Vocal fold mobility	50 (100%)	0	50 (100%)	0	0
8.	Glottal gap size	43 (87.8%)	6 (12.2%)	39 (79.6%)	10 (20.4%)	1.19
9.	Glottal closure pattern	43 (89.6%)	5 (10.4%)	39 (79.6%)	10 (20.4%)	1.85
10.	Erythema	38 (76%)	12 (24%)	12 (24%)	38 (76%)	27.01**
11.	Ventricular fold compression	23 (46%)	27 (54%)	20 (41.7%)	28 (58.3%)	0.18
12.	Organized lesions	50 (100%)	0	47 (94%)	3 (6%)	3.09

** Significant at $P < 0.01$,

* Significant at $P < 0.05$

Table 3 Acoustic voice parameters among nonsmokers and smokers

S. No.	Acoustic voice parameters	Nonsmokers		Smokers		<i>t</i>
		Mean	SD	Mean	SD	
1.	F0 (Hz)	139.33	17.05	131.39	14.54	2.51*
2.	Jitter (%)	0.33	0.42	0.57	0.73	2.00*
3.	Shimmer (%)	1.83	0.95	2.33	1.15	2.37*
4.	F0 tremor (Hz)	2.06	0.95	3.00	1.60	3.54*
5.	NNE (dB)	−13.37	2.73	−12.02	3.66	2.09*
6.	HNR (dB)	26.79	5.94	24.32	6.94	1.91
7.	SNR (dB)	25.26	5.51	22.90	6.40	1.98*
8.	Amplitude tremor (Hz)	1.76	1.15	2.13	1.33	1.52
9.	MPT (Seconds)	12.82	2.73	11.44	2.93	2.44*
10.	s/z ratio	1.00	0.13	1.09	0.24	2.21*

SD standard deviation,

* Significant at $P < 0.05$

Lower values of fundamental frequency (F0) were noted among smokers as compared to nonsmokers ($t = 2.51$, $P < 0.05$). Smokers showed raised values of jitter ($t = 2$), shimmer ($t = 2.37$), F0 tremor ($t = 3.54$), normalized noise energy (NNE) ($t = 2.09$) and s/z ratio ($t = 2.21$) as compared to nonsmokers (statistically significant at $P < 0.05$). Lower values of signal noise ratio (SNR) ($t = 1.98$) and maximum phonation time (MPT) ($t = 2.44$) were noted among smokers as compared to nonsmokers (statistically significant at $P < 0.05$). No significant difference was observed in harmonic noise ratio (HNR) ($t = 1.91$) and amplitude tremor ($t = 1.53$) between smokers and nonsmokers ($P > 0.05$).

Observation of Electroglottographic Parameters Among Smokers and Nonsmokers

EGG parameters with mean and standard deviation are shown in Table 4. In present study 14 parameters were

observed in non-dysphonic adult male smokers and nonsmokers (50 each) via Electroglottograph (Tiger DRS) and the output EGG signals analyzed by computerized software package (Dr. Speech Vocal Assessment).

Lower values of EGG fundamental frequency (F0) were noted among smokers as compared to nonsmokers ($t = 2.52$, $P < 0.05$). Smokers showed raised values of EGG jitter ($P = 2.38$), EGG shimmer ($t = 2.28$), EGG F0 tremor ($t = 2.22$) and opening rate ($t = 2.11$) as compared to nonsmokers (statistically significant at $P < 0.05$). Lower values of closing rate ($t = 2.17$, $P < 0.05$) were noted among smokers as compared to nonsmokers. No statistically significant difference was observed in EGG normalized noise energy (NNE) ($t = 0.44$), EGG harmonic noise ratio (HNR) ($t = 0.21$), EGG signal noise ratio (SNR) ($t = 0.32$), EGG amplitude tremor ($t = 0.95$), contact quotient ($t = 0.25$), contact index ($t = 1.74$), contact quotient perturbation ($t = 0.15$) and contact index perturbation ($t = 1.02$) between smokers and nonsmokers ($P > 0.05$).

Table 4 Electroglottographic parameters among nonsmokers and smokers

S. No.	Electroglottographic parameters	Nonsmoker		Smoker		<i>t</i>
		Mean	SD	Mean	SD	
1.	EGG F0 (Hz)	139.37	17.22	131.43	14.57	2.52*
2.	EGG jitter (%)	0.30	0.28	0.51	0.68	2.38*
3.	EGG shimmer (%)	0.66	0.44	1.04	1.07	2.28*
4.	EGG F0 tremor (Hz)	2.29	1.35	2.93	1.51	2.22*
5.	EGG NNE (dB)	−31.28	2.97	−31.54	3.84	0.44
6.	EGG HNR (dB)	34.37	3.11	34.26	4.20	0.21
7.	EGG SNR (dB)	33.11	2.98	33.34	4.12	0.32
8.	EGG amplitude tremor (Hz)	1.47	0.51	1.57	0.63	0.95
9.	Contact quotient (%)	71.20	3.51	71.35	3.15	0.25
10.	Contact index (CI)	−0.06	0.13	−0.11	0.12	1.74
11.	CQ perturbation (%)	0.52	0.49	0.54	0.54	0.15
12.	CI perturbation (%)	14.40	12.33	12.10	12.26	1.02
13.	Opening rate (%)	52.47	5.23	54.46	4.62	2.11*
14.	Closing rate (%)	47.47	5.26	45.40	4.62	2.17*

SD standard deviation,

* Significant at $P < 0.05$

Discussion

The purpose of this study was to compare the larynx of smokers and nonsmokers in regard to structure and function via videostroboscopic evaluation, acoustic voice analysis and electroglottography. The following discussion is based on the observations made on 50 nonsmokers and 50 smokers.

Discussion is further grouped under following headings:

A. Laryngeal Characteristics (Parameters) Determined by Videostroboscopy for Nonsmokers and Smokers

The primary findings observed in smokers were as follows:

I. Abnormal vocal fold edge

Sataloff (2005) states that smoking causes chronic irritation of the vocal folds, resulting in microscopic alterations in the vocal fold epithelium [5]. Abnormal vocal fold edge in smokers may result due to chronic irritation and histological alteration caused by smoking.

In present study significant difference between abnormal vocal fold edge findings was observed in smokers as compared with nonsmokers control group. However, Awan and Morrow [6] observed no statistically significant relationship between vocal fold edge abnormalities in smokers as compared to nonsmokers. Although they observed that 50% of the smokers were having some type of vocal fold edge abnormality in comparison with 32% of the nonsmokers. In present study 31.9% of the smokers were rated as having some type of vocal fold edge abnormality in comparison with 6.1% of the nonsmokers.

The most common vocal fold edge abnormality observed in smokers was irregular vocal cord edge followed by swollen vocal fold edge. Irregular vocal fold edge is due to histological alteration caused due to chronic irritation of smoking. Swollen vocal fold edge can be attributed to edema of vocal folds caused by smoking [7].

II. Abnormal Texture

Abnormal texture of vocal folds in smokers may also result due to microscopic alteration in the vocal fold epithelium caused by chronic irritation of vocal folds by smoking [5]. In present study significant difference between abnormal texture findings was observed in smokers as compared with nonsmokers control group. However, Awan and Morrow [6] observed no significant relationship between vocal fold texture abnormalities in smokers as compared to nonsmokers. The most common vocal fold texture abnormality observed in smokers was of mild roughness followed by moderate roughness.

III. Presence of Edema

Edema of the vocal folds is characterized by inflammation and capillary leakage primarily in the superficial layers of the vocal folds. Chronic inflammation may result due to exposure to noxious agents such as cigarette smoke resulting in edema of vocal folds.

In present study significant difference in the presence of edema was noted in smokers when compared with a nonsmoker control group. This result is consistent with earlier reports of edematous vocal folds in smokers [6, 8, 9].

Only mild/moderate degree of edema was observed among cases of edema in smokers. Severe edema and Reinke's edema was not observed in present study among smokers. It may be because severe edema and Reinke's edema results in hoarseness of voice and in present study, subjects with complaint of voice change were excluded.

IV. Presence of Erythema

As for edema, erythema in smokers is also a reaction to irritation and trauma of the vocal folds. During smoking, the vocal fold tissues may become irritated and dehydrated by the inhaled heated noxious gases. In turn, irritated and dehydrated vocal fold mucosa may become traumatized during phonation, particularly if the subject is using hyperfunctional behaviors to overcome the increased mass of vocal folds as expected due to edematous vocal folds.

In addition to edema, the current study found a significant increase in the presence of erythema in male smokers when compared with nonsmoking males. This finding is consistent with and support previous descriptions of the laryngeal structures of smokers [6, 8, 10].

Among cases of erythema in smokers, in most of the cases mild erythema was observed followed by moderate degree of erythema. In only 4% cases of smokers severe erythema was observed. It may be because severe erythema usually presents with hoarseness of voice, and in present study subjects complaining of voice change were excluded from study.

V. Abnormal Mucosal Cover

Abnormal mucosal cover in smokers may also result due to histological changes in vocal fold epithelium as a result of chronic irritation and inflammation caused by smoking. Abnormal mucosal cover in smokers may also result from edema of vocal fold caused by the cigarette fumes, as the edema generally involves the superficial layers of the vocal fold.

Abnormal mucosal cover findings in smokers are unique to the use of the videostroboscopic method and would not

be observable via standard laryngoscopy because of the high rate of vocal fold vibration.

In current study significant difference was observed between abnormal mucosal cover findings in smokers as compared with nonsmokers control group. However, Awan and Morrow observed no statistically significant relationship between mucosal cover abnormalities in smokers as compared to nonsmokers [6]. Although their results indicated that 40% of smokers had an abnormal mucosal cover as compared with 26% of nonsmokers. In present study 38.3% of the smokers were rated as having some type of vocal fold edge abnormality in comparison with 15.2% of the nonsmokers.

The most common mucosal cover abnormality observed in smokers was thick mucosal cover. This may be due to chronic inflammatory response of vocal folds to smoking.

VI. Abnormal phase symmetry

The presence of abnormal phase symmetry in smokers may be due to associated edema of vocal folds as a result of smoking. If the edema within vocal fold tissues is unequal (i.e., asymmetric mass), the folds may vibrate at different rates, and thus they may be asymmetrical in their movements. Abnormal phase symmetry may also result from chronic irritation of the vocal folds resulting in microscopic alterations in the vocal fold epithelium [5]. Abnormal phase symmetry may also be due to the presence of developing lesion within vocal fold tissue, and it has been associated with chronic laryngitis [8]. It may be these microscopic changes in the vocal fold epithelium and edema that resulted in the phase asymmetries observed in the vocal fold vibration of the smokers in present study.

Abnormal findings of phase symmetry are unique to the use of the videostroboscopic method and would not be observable via standard laryngoscopy because of the high rate of vocal fold vibration. In current study significant difference was observed between abnormal phase symmetry findings in smokers as compared with nonsmokers control group. Awan and Morrow [6] also observed the same results in female smokers via videostroboscopy.

Among abnormal phase symmetry cases of smokers, most commonly observed finding was of 50% asymmetrical phase symmetry. Out of 3 cases of organized lesions, in one case of leukoplakia 50% asymmetrical phase symmetry was observed.

VII. Abnormal Pliability/Stiffness

Abnormalities in vocal fold pliability or stiffness may result due to long standing edema because of smoking. In present study significant difference between abnormal pliability or stiffness findings was observed. However, Awan

and Morrow [6] observed no significant relationship between pliability or stiffness abnormalities in smokers as compared to nonsmokers. This may be because they included only young smokers in their study and abnormalities in vocal fold pliability or stiffness result after long standing edema because of smoking. In present study middle and old age groups were also included; as a result long standing effects of smoking on vocal folds were also seen. The most common vocal fold pliability or stiffness abnormality observed in smokers was mild stiffness followed by moderate stiffness.

VIII. Other Videostroboscopic Parameters in Smokers

Ratings of vocal fold mobility, glottal gap size, glottal closure pattern, ventricular fold movement and presence of lesion were not observed to have any significant relationship to smoking.

In current study, all subjects (smokers and nonsmokers) had normal vocal fold mobility. Awan and Morrow [6] also observed normal vocal fold mobility in all smokers and nonsmokers subject.

No significant difference was observed between abnormal glottal gap size findings. However, Awan and Morrow [6] observed significant relationship between glottal gap size abnormalities in smokers as compared to nonsmokers. They attributed this change to combination of irritation and tissue change in the arytenoid region of smokers affecting the ability to approximate the vocal folds during phonation, resulting in increased glottal gap size. Increased glottal gap may be secondary to vocal hyperfunction used to compensate for edematous or irritated vocal folds. In present study also increased glottal gap size abnormality was seen in smokers (20.4%) as compared with nonsmokers (12.2%). However, this difference was not statistically related.

In present study, no significant difference observed between abnormal glottal closure pattern findings. This result is consistent with earlier study [6]. Most subjects (both smokers and nonsmokers) in current study had a consistent complete glottal closure during the closed phase of phonation. Most commonly observed abnormal glottal closure pattern in smokers was spindle shaped glottal closure pattern followed by irregular glottal closure pattern.

No significant difference observed between abnormal ventricular fold movements in both group. No significant difference was observed in presence of organized lesions. This result is consistent with earlier study [6]. In current study, 3 cases of organized lesions were observed in smokers, which included 2 cases of leukoplakia and 1 case of atrophied vocal folds. Leukoplakia may be due to chronic irritation caused by smoking and is considered precancerous. In both the cases of leukoplakia

microlaryngeal surgery and vigilant follow-up was advised. But both the subjects did not come for follow-up.

B. Acoustic Voice Parameters Among Nonsmokers and Smokers

Lower Values of Fundamental Frequency (F0)

Fundamental Frequency (F0) refers to the most frequently occurring frequency that characterizes a particular vocal production. Changes in fundamental frequency (F0) characteristics are most commonly observed characteristics of the smoking voice. It may reflect underlying differences in the structure and function of the laryngeal mechanism. Lowered voice F0 may also be attributed to changes in vocal fold mass caused by smoking [11].

In present study, lower values of fundamental frequency (F0) were noted among smokers as compared to nonsmokers. This finding is consistent with and support previous descriptions of the voice of smokers [11–13].

Raised Values of Jitter

Jitter refers to cycle-to-cycle variation in signal frequency. Raised values of jitter in smokers may also be attributed to acoustic differences for the smoking voice and reflect underlying differences in the structure of the larynx due to smoking. Increased Jitter values are also associated with phonatory instability due to aging, neurological disorder and various laryngeal pathologies [14, 15]. Voice perturbation is a probable indicator for a physiological disorder.

In present study, smokers showed raised values of jitter as compared to nonsmokers. This finding is consistent with the results obtained in previous studies [12, 16–18].

Raised Values of Shimmer

Shimmer refers to cycle-to-cycle variation in signal amplitude. As for jitter, raised shimmer in smokers is also attributed to underlying structural differences of laryngeal epithelium due to smoking.

In present study, raised values of shimmer were obtained in smokers as compared to nonsmokers. In earlier studies also similar results were obtained [12, 18].

Raised Values of F0 Tremor

Fundamental frequency tremor (F0 tremor) is the frequency of the lowest frequency modulation component. Raised values of F0 tremor may also result from microscopic alterations in the vocal fold epithelium due to chronic irritation caused by smoking resulting in acoustic difference.

In present study, raised values of F0 tremor were obtained in smokers as compared to nonsmokers. Current study supports the findings obtained in previous studies [16].

Raised Values of Normalized Noise Energy (NNE)

The NNE assesses the relative level of vocal noise to that of harmonics [19]. In present study, raised values of NNE were obtained in smokers as compared to nonsmokers. However, Damborenea et al. [12] observed no significant difference in values of NNE for smokers and nonsmokers group.

The NNE has been shown to correlate with perceived breathiness of voice [20]. So, increased glottal gap size in smokers as compared to nonsmokers may account for breathy voice resulting in raised NNE. However, despite few published studies used NNE as an outcome measure to distinguish pathological from normal voices, but its clinical usefulness is still unclear [19, 21].

Lower values of signal noise ratio (SNR)

SNR is defined as the decibel ratio of the total energy in the acoustic speech signal to the energy in the aperiodic or noise component [22]. SNR is the ratio of total signal energy to inharmonic (noise) energy. In our study, lower values of SNR were observed in smokers as compared to nonsmokers.

Lower Values of Maximum Phonation Time (MPT)

MPT is a clinical test of glottal competence [23] where maximum time a person can sustain a tone on one continuous expiratory breath is calculated. Multiple factors influence MPT, such as respiratory capacity and function, phonatory function, resonance, practice, frequency, intensity, instructions, and, potentially, vowel choice. Smoking affects both respiratory and phonatory functions.

In present study, lower values of MPT were observed in smokers as compared to nonsmokers. Lee et al. [24] also observed shorter mean maximum phonation times (MPT) in smokers as compared to nonsmokers.

However, Schutte (1992) described MPT as a non-reliable measure and of limited clinical value as it does not distinguish between inefficient glottal valving from reduced poor respiratory reserve and poor driving pressure of vocal fold vibration [25, 26].

Raised Values of s/z Ratio

The s/z ratio is a variation of the maximum phonation time whereby the maximum sustained time for a speaker to

make both an “S” and “Z” sound are recorded [27, 28]. S/Z ratio assesses both respiratory and phonatory efficiency [29]. A ratio of 1.0 with normal duration of production indicates that the respiratory ability is normal and there is no vocal pathology. Smoking affects phonatory physiology by affecting the structure and functions of the laryngeal mechanism and may result in raised values of s/z ratio.

In present study, raised values of s/z ratio were obtained in smokers (1.09 ± 0.24) as compared to nonsmokers control group (1.0 ± 0.13). Shipley and McAfee [30] states that in vocal pathologies, higher values of s/z ratio are obtained.

Harmonic Noise Ratio (HNR)

HNR is the ratio of the harmonic energy to inharmonic (noise) energy. No significant difference was observed in HNR in smokers as compared to nonsmokers. Damborenea et al. [12] also observed no significant difference for HNR in smokers as compared to nonsmokers.

Amplitude Tremor

Amplitude tremor is the frequency of the intensive low frequency amplitude modulation component. No significant difference was observed in amplitude tremor in smokers as compared to nonsmokers. However, Gonzalez and Carpi [16] observed differences in amplitude Tremor Frequency for smokers and nonsmokers.

C. Electroglottographic Parameters Among Nonsmokers and Smokers

Some EGG parameters differed between smokers and nonsmokers, which can be attributed as consequence of histological changes caused by tobacco.

The primary findings observed in present study were as follows:

Lower values of EGG fundamental frequency (EGG F0)

Fundamental frequency is an acoustic measure that directly reflects the vibrating rate of the vocal folds and is expressed in Hz. In present study; lower values of EGG fundamental frequency (EGG F0) were noted among smokers as compared to nonsmokers. This finding is consistent with and support previous descriptions of the voice of smokers [11–13]. Guimarães and Abberton [17] did electrolaryngography assessment in smokers and nonsmokers and observed that mean EGG F0 values were lower in smokers as compared to nonsmokers for different task performance.

Raised Values of EGG Jitter

EGG jitter (frequency perturbation) is defined as the degree of cycle-to-cycle variability of the fundamental frequency in the EGG signals. Smoking may result in raised values of jitter by causing differences in the microstructure of the larynx.

In present study, smokers showed raised values of EGG jitter as compared to nonsmokers. This finding is consistent with the results obtained in previous studies [12, 16, 18]. Guimarães and Abberton [17] via electrolaryngography assessment in smokers and nonsmokers found raised values of EGG jitter in smokers as compared to nonsmokers for different task performance.

Raised Values of EGG Shimmer

EGG shimmer (amplitude perturbation) is a measurement of the amount of peak amplitude variability from one cycle to the next cycle in the EGG signals. Raised shimmer in smokers may also be attributed to underlying structural differences of laryngeal epithelium due to smoking. Scientific literature suggests a very clear relationship between changes of vocal cord epithelium and the quantity of tobacco consumed over a lifetime [31].

In present study, raised values of EGG shimmer were obtained in smokers as compared to nonsmokers. In earlier studies also similar results were obtained [12, 18].

Raised Values of EGG F0 Tremor

Only jitter (frequency perturbation) is not sufficient to accurately describe an aberration in a patient's voice. Jitter values may be within normal limits in a patient who demonstrates a breathy voice quality; and periodic modulation over many glottal periods called F0 tremor should be differentiated from cycle-to-cycle modulation. Raised values of F0 tremor may also result from microscopic alterations in the vocal fold epithelium due to chronic irritation caused by smoking resulting in acoustic difference.

In present study, raised values of EGG F0 tremor were obtained in smokers as compared to nonsmokers. Present study supports the findings obtained in previous studies [16].

Raised Values of Opening Rate

In an EGG waveform, opening rate is defined graphically as the percentage of each period in which the vocal folds are moving apart while the glottis is closed. In present study, raised values of opening rate were obtained in smokers as compared to nonsmokers.

Lower Values of Closing Rate

In an EGG waveform, closing rate is defined graphically as the percentage of each period in which the vocal folds are moving together while the glottis is closed. In present study, lower values of closing rate were obtained in smokers as compared to nonsmokers.

Other Electroglottographic Parameters in Smokers

In present study, no statistically significant difference was observed in EGG NNE, EGG HNR, EGG SNR, EGG amplitude tremor, contact quotient, contact index, contact quotient perturbation and contact index perturbation between smokers and nonsmokers.

Damborenea et al. [12] also observed no significant difference in values of NNE and HNR between smokers and nonsmokers. However, Gonzalez and Carpi [16] found altered amplitude tremor Frequency in smokers as compared to nonsmokers. There is paucity of information in the literature describing other EGG parameters in smokers as compared to nonsmokers group.

Summary

The current study observed significant relationships between smokers and several videostroboscopic, acoustic voice analysis and EGG parameters on the anatomy and physiology of the laryngeal mechanism.

On videostroboscopy a significant relationship among smoking and abnormal vocal fold edge, abnormal texture, edema, erythema, abnormal mucosal cover, abnormal phase symmetry and abnormal pliability/stiffness were observed. More importantly, the significance of abnormal mucosal cover and abnormal phase symmetry are parameters of vocal fold vibration that can only be adequately viewed and rated via the videostroboscopic method. The most commonly observed laryngeal characteristic via videostroboscopy in smokers was erythema.

Our results showed that smoking has a clear effect on some acoustic voice parameters. Fundamental frequency (F0) was significantly affected by smoking. Lower values of F0 were observed in smokers. Perturbation parameters (jitter, shimmer) were significantly higher for the smoker participants. Vocal tremor parameter (F0 tremor) seems to be significantly increased by smoking in males. Noise evaluation measurements (normalized noise energy and signal noise ratio) were also altered significantly in smokers. Raised values of NNE and lower values of SNR were observed in smokers. Lower values of maximum phonation time (MPT) and raised values of s/z ratio were also observed in smokers.

Our results showed that smoking has a clear effect on some voice parameters evaluated via electroglottography. Lower values of Fundamental frequency (EGG F0) were observed in smokers. Perturbation parameters (EGG jitter, EGG shimmer) were significantly higher for the smoker participants. Vocal tremor parameter (EGG fundamental frequency tremor) seems to be significantly increased by smoking in males. Raised values of opening rate and lower values of closing rate were also significantly observed in smokers. Fundamental frequency is the most important voice parameter affected by aging in present study.

Conclusion

The current study on videostroboscopic examination of larynx shows that smoking has a significant effect on laryngeal structures. Objective voice parameters evaluated via acoustic voice analysis and electroglottography also focuses relation between smoking and the deranged voice in present study. A combination of voice parameters seems to suggest a possible neurological effect of nicotine or some other chemical component of tobacco on the voice. It is our hope that this research may contribute in a small way in increasing awareness of the detrimental effects of smoking and decrease the prevalence of smoking among the male population.

Conflict of interest None.

References

1. Myerson MC (1964) The human larynx. Charles C. Thomas Publishers, Springfield, pp 186–190
2. Hirano M, Bless DM (1993) Videostroboscopic examination of the larynx. Singular Publishing, San Diego
3. Stemple JC, Glaze LE, Gerdeman BK (1995) Clinical voice pathology: theory and management, 2nd edn. Singular Publishing, San Diego
4. SPSS 10.0 [Computer Software] (1999). SPSS, Chicago
5. Sataloff RT (2005) Professional voice: the science and art of clinical care, 3rd edn. Plural Publishing, Inc., San Diego
6. Awan SN, Morrow DL (2007) Videostroboscopic characteristics of young adult female smokers vs. nonsmokers. *J Voice* 21(2):211–223
7. Dworkin JP, Meleca RJ (1997) Vocal pathologies: diagnosis treatment, and case studies. Singular Publishing, San Diego
8. Colton RH, Casper JK (1996) Understanding voice problems: a physiological perspective for diagnosis and treatment, 2nd edn. Williams & Wilkins, Baltimore
9. Marcotullio D, Magliulo G, Pezone T (2002) Reinke's edema and risk factors: clinical and histopathologic aspects. *Am J Otolaryngol* 23:81–84
10. Berliti S, Omidi M (2005). Chronic laryngitis, infectious or allergic. Available: <http://www.emedicine.com/ent/topic354.htm>. Accessed May 29, 2005

11. Gilbert HR, Weismer CG (1974) The effects of smoking on the speaking fundamental frequency of adult woman. *J Psycholinguist Res* 3(3):225–231
12. Damborenea TJ, Fernandez LR, Llorente AE, NayaGálvez MJ, Marín GC (1999) The effect of tobacco consumption on acoustic voice analysis (Spanish). *Acta Otorrinolaringol Esp* 50(6):448–452
13. Wiskirska-Woźnica B, Obrebowski A, Swidziński P, Wojnowski W, Wojciechowska A (2004) Effect of smoking on phonation. *Przegl Lek* 61(10):1068–1070
14. Kent J, Kent R, Rosenbek JC et al (1992) Quantitative description of dysarthria in women with amyotrophic lateral sclerosis. *J Speech Hear Res* 35:723–733
15. Wolfe V, Cornell R, Palmer C (1991) Acoustic correlates of pathological voice types. *J Speech Hear Res* 34:509–516
16. Gonzalez J, Carpi A (2004) Early effects of smoking on the voice: a multidimensional study. *Med Sci Monit* 10(12):649–656
17. Guimarães I, Abberton E (2005) Health and voice quality in smokers: an exploratory investigation. *Logoped Phoniatr Vocol* 30(3–4):185–191
18. Chai L, Sprecher AJ, Zhang Y, Liang Y, Chen H, Jiang JJ (2010) Perturbation and nonlinear dynamic analysis of adult male smokers. *J Voice* 25(3):342–347
19. Kasuya H, Ogawa S, Mashima K, Ebihara S (1986) Normalized noise energy as an acoustic measure to evaluate pathologic voice. *J Acoust Soc Am* 80:1329–1334
20. McAllister A, Sundberg J, Hibi SR (1997) Acoustic measurements and perceptual evaluation of hoarseness in children's voices. *Logoped Phoniatr Vocol* 23:27–38
21. Hirano M, Tanaka Y, Tanaka S, Hibi S (1990) Transcutaneous intrafold injection for unilateral vocal fold paralysis: functional results. *Ann Otol Rhinol Laryngol* 99:598–604
22. Nittrouer S, McGowan RS, Milenkovic PH et al (1990) Acoustic measurement of men's and women's voices: a study of context effects and covariation. *J Speech Hear Res* 33:761–775
23. Hirano M (1981) Clinical examination of voice. Springer-Verlag, Wien
24. Lee L, Stemple JC, Geiger D, Goldwasser R (1999) Effects of environmental tobacco smoke on objective measures of voice production. *Laryngoscope* 109(9):1531–1534
25. Schutte HK (1992) Integrated aerodynamic measurements. *J Voice* 6:127–134
26. Baken RJ, Orlikoff RF (2000) Airflow and volume. In: Baken RJ, Orlikoff RF (eds) Clinical measurements of speech and voice. Singular Thomson learning, San Diego, pp 337–391
27. Boone DR (1977) The voice and voice therapy. Prentice-Hall, Englewood Cliffs
28. Eckel F, Boone DR (1981) The s/z ratio as an indicator of laryngeal pathology. *J Speech Hear Disord* 46:147–149
29. Boone DR, McFarlane SC (2000) The voice and voice therapy, 6th edn. Allyn and Bacon, Boston
30. Shipley & McAfee, (1992). Assessment in Speech-language Pathology: A resource manual. San Diego, CA: Singular Publishing Group, Inc. Fant G: Theory of speech production, The Hague, 1960, Mouton
31. Muller KM, Krohn BR (1980) Smoking habits and their relationship to precancerous lesions of the larynx. *J Cancer Res Clin Oncol* 96:211–217