

Filtered and un-filtered cigarette smokers: Variance of acoustic, aerodynamic and perceptual measures

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Abstract

Voice is the primary means of communication and also plays a significant role in individuals' daily life. It expresses their personal information like social status, personal qualities, and the emotional state. A wide range of factors such as quality, strength, accuracy, flexibility of sound affects the physiology of healthy voice production (Boone, 2013) ^[1]. People can either smoke, chew or sniff tobacco. Smoking is the inhalation of smoke by burning tobacco which is wrapped in cigarettes, pipes and beedis. It causes irritation of the larynx which has a chance for developing damage and ailment in future. The foremost aim of the study is to analyze the acoustic voice characteristics using PRAAT software version 6.0.32, aerodynamic measures using Maximum Phonation Duration (MPD), perceptual voice characteristics using Grade, Roughness, Breathiness, Asthenia and Strain (GRBAS) rating scale and self-perception of voice using Voice Handicap Index 10 (VHI-10) among filtered and un-filtered cigarette smokers. Thirty men aged 25 to 50 years were recruited for the study. They were grouped as Group A: 15 filtered cigarette smokers and Group B: 15 un-filtered cigarette smokers based on their smoking products. The test outcomes were analyzed using descriptive analysis and Paired sample 't' test in SPSS version 25. A significant difference in acoustical voice characteristics was noted among both the groups. The results highlighted that the smoking product had a significant impact on the voice characteristics. Therefore, it should be considered as an important factor during the assessment and management of voice.

Keywords: voice, acoustic analysis, mpd, grbas, vhi 10 and smoking product

Introduction

Voice is the primary means of communication and also plays a significant role in individuals' daily life. An individual's voice reflects their personal information like social status, personality, and the emotional state through the interaction of wide range of factors like quality, strength, accuracy and flexibility. These factors also contribute to healthy voice production (Boone, 2013) ^[1] whereas disruption of any of these resulted from anatomical changes of larynx can lead to voice disorder. There are numerous causes for dysphonia in which smoking is considered as a typical risk factor of voice health (Pavlovskaya, 2018) ^[11, 21], as continuous smoking can lead to vocal fold carcinoma which can significantly affect voice production. Cigarette consumption and duration of cigarette smoke exposure are found to be correlated with the severity of histological lesions in Smokers vocal fold, with a longer duration of smoke exposure being associated with worse histological damage (Gonzalez J, 2004) ^[3, 32].

Smoking is the inhalation of smoke by burning tobacco which is wrapped in cigarettes and beedis. According to Pinar *et al* (2016) ^[4], smoking is considered as one of the most common injurious habit in the world, exclusively among the young adult male population. Moreover, smoking can have detrimental effect on one's physical wellbeing as it can pave the way for various health hazards including laryngeal abnormalities. It may affect voice directly as it is an etiology associated with organic voice disorders rather than functional voice disorders due to misuse and abuse of

voice (Pavlovskaya, 2018; Byeon 2015; Tamaki, 2018) ^[11, 2, 5, 6, 7] Excessive smoking irritates the vocal folds and dry vocal fold mucosa and also results in its inflammation. It leads to sputum, coughing and irritation of vocal folds which results in voice change (Parmar, 2018) ^[8]. There exist a clear association between tobacco use and laryngeal pathology (Hamdan, 2011) ^[9] which was supported by the findings that smokers are more likely to develop a laryngeal disease when compared to non-smokers (Pavlovskaya, 2018 & Byeon, 2013) ^[11, 2, 12]. Byeon (2015) ^[5, 6] also stated that smokers had 1.8 times greater risk of self-reported problems and 1.6 times higher risk of developing a laryngeal disorder than non-smokers.

The effects of smoking on vocal health can be chiefly classified into three categories based on its impact on structure, voice characteristics and self-perception. Liu (2019) ^[13] & Duarte (2006) ^[14] conducted few experiments on rats and pigs to assess the effects of smoking on the larynx and found that it causes anatomical changes in laryngeal system. Pathologies like leukoplakia, laryngitis and Reinke's edema were reported in incessant smokers and they were categorized as high risk for laryngeal, pharyngeal and oral cancer (Boone, 2013) ^[1]. Murphy (1987) ^[15] also stated that tobacco smoke causes edema in vocal folds which leads to reduction in fundamental frequency (F0).

Smoking is also known to alter voice characteristics (Feierabend, 2009 ^[16]; Tafiadis, 2018 ^[10, 17, 18]; Tuhanioglu, 2019; Tafiadis, 2018) by bringing acoustical changes in fundamental frequency (F0), jitter (%), shimmer (dB) and

Harmonics to Noise Ratio (HNR), which plays a key role in determining the voice quality (Lee, 2018; Gonzalez, 2004; Tafiadis, 2017) [3, 32, 21]. In addition, greater abnormalities were found in amplitude, symmetry and cycles of vocal fold vibrations while analyzing voice samples of smokers (Pinar, 2016) [4]. The decline in fundamental frequency of smoker’s voice is also proved to be associated with increase in vocal fold mass. Frequency perturbation parameters and vocal tremor parameters also varies in healthy smokers when compared to nonsmokers (Gonzalez, 2004) [3, 32]. Besides, there are evidence which shows 30 minutes of smoking may result in a vocal pitch drop and an increase in laryngeal secretions and vocal fold vasodilation (Hamdan, 2011) [9]. As well, smokers experience voice breaks and vocal fatigue (Simberg, 2015; Pinar, 2016, Stachler, 2018) [22, 4, 23] along with changes in voice quality particularly reflected in shimmer and HNR (Tuhanioglu, 2019; Tafiadis, 2017) [21]. Apparently, the subjective perception, as well as self-perception of voice in smokers are also affected, which were rated severe in a study conducted by Tafiadis in 2017 [21]. In short, smoking negatively affects objective voice quality (Freeman, A 2013) [25] together with subjective voice perception (Tafiadis, 2018&Tafiadis *et al*, 2018) [10, 17, 18] and thereby vocal pathologies caused due to smoking perhaps have potential effect on daily activities, occupations, and social interactions (Ma &Yiu, 2001) [26]. The effect of smoking on larynx varies based on the type of tobacco product used. Typically, smoked tobacco products comprise of cigarettes, beedis, cigars and kreteks. It is majorly classified into two types: filtered and un-filtered cigarettes based on the substances used to manufacture them. In filtered cigarettes, a filter is made from the material called cellulose acetate which is used to make camera film with the utmost purpose to reduce the intake of nicotine and tar substances by the smoker. Invisible perforations in the filtered cigarette tip act as a semi-permeable membrane which prevents larger parts of tar and nicotine from entering into the smoker’s mouth. Instead, it let a large amount of air along with minimum amount of smoke to flow through it. So, during each drag unfiltered cigarette provides nicotine in its full capacity whereas filtered one will eliminate most of the addictive particles. Hence, un-filtered cigarette smokers have a high risk of vocal abnormality than filtered cigarette smokers.

Despite the fact that several studies have been done to assess the relationship among the vocal health and smoking evidently, still there is no sufficient evidence to prove which tobacco product affects the vocal health more. Therefore, the present study is aimed to analyze the same linear relationship among the acoustic and perceptual characteristics, aerodynamic measures and self-perceptual characteristics of voice between filtered and un-filtered cigarette smokers.

Need of the Study

Over the past few decades, the literature provides strong evidences about the relationship between chronic smoking and laryngeal pathology. But still, studies predicting the effects of smoking filtered and un-filtered cigarettes on vocal characteristics are scarce. So, it is crucial to identify which has more effect on larynx and leads to severe vocal abnormalities. In addition, the current study may be beneficial to help individuals’ transition from unfiltered to filtered cigarettes as smoking cessation is not necessarily successful, though ideal. Hence the study can be considered relevant, in the backdrop of smoking surge in youngsters, to reduce the devastating impact of smoking in one’s health.

Objectives of the Study

The major objectives of the study are as follows: to analyze (i) acoustical voice characteristics (ii) aerodynamic measures (iii) perceptual voice characteristics and (iv)self-perception of voice problems among filtered and un-filtered cigarette smokers.

Method of the Study

Participants

Thirty males aged 25-50 years were recruited within urban limits by using simple random sampling method. Participants were grouped into two namely Group A and Group B based on the smoking product they use. Group A includes fifteen filtered cigarette smokers (mean age=35.2 years) wherein Group B consists of fifteen unfiltered cigarette smokers (mean age=36.6 years). The below mentioned table depicts the demographic details such as age, height, weight and BMI among both the groups.

Table 1: Demographic Details of the Participants^a

Characteristics	Group A	Group B
Age, years, mean (SD)	35.2(5.82)	36.6(7.46)
Height, inches, mean (SD)	157.7 (5.35)	159.7(6.30)
Weight, kg, mean (SD)	64.5(6.77)	62.8(6.46)
BMI, mean (SD)	25.94 (2.39)	24.61 (2.03)

Source: Primary data

^aN=30

Group A: Filtered cigarette smokers; Group B: Unfiltered cigarette smokers

Abbreviations: BMI (Body Mass Index) and SD (Standard Deviation).

Healthy individuals with habit of smoking at least 3 cigarettes per day for minimum of one year were included as participants. Individuals with upper respiratory tract infections, vocal nodules and other voice related problems were excluded. Demographic data (table 1) and smoking properties including duration of smoking and number of cigarette consumption per day (table 2) were collected from all the participants.

Table 2: Smoking properties-descriptive statistics

Smoking properties	N		%		Mean	
	Group A	Group B	Group A	Group B	Group A	Group B
<i>Duration of smoking (in years)</i>						
01-05	08	04	53.3	26.6	3.375	3.25
06-10	06	07	40	46.6	7.834	8.85
>10	01	04	6.6	26.6	15	15
<i>No. of cigarettes smoked per day</i>	Group A	Group B	Group A	Group B	Group A	Group B
01-05	06	07	40	46.6	3.8	4.85
06-10	09	05	60	33.3	7.4	8.33
>10	0	03	0	20	0	13.5

Source: Primary data

Materials

Acoustic Analysis: PRAAT software version 6.0.32

Acoustic parameters such as fundamental frequency (F0), jitter, shimmer, and Harmonics to Noise Ratio (HNR) were measured in the present study using PRAAT.

Aerodynamic Evaluation: Maximum Phonation Duration (MPD)

MPD is a quick and simple aerodynamic measure performed by instructing the participants to sustain a vowel sound (|a|) produced in a single deep breath at a comfortable loudness and pitch as long as they can.

Perceptual Evaluation: Grade, Roughness, Breathiness, Asthenia and Strain (GRBAS) rating scale

It evaluates auditory-perceptual measures which is used subjectively to assess the voice quality and degree of hoarseness based on the recorded speech sample of the participants. The scoring ranges from 0 to 3 where 0 is normal, 1 is a slight degree, 2 is a medium degree, and 3 is a high degree.

Self-Perceptual Evaluation: Voice Handicap Index 10 (VHI-10)

VHI-10 consists of ten questions. They were self-administered by the participants in which they can score 0 for never, 1 for almost never (occasionally), 2 for sometimes, 3 for almost always and 4 for always. The maximum score is 40 whereas scores above 11 is considered as abnormal.

Procedure

The study objective and purpose were clearly explained to the participants. The demographic details of the participants, number of cigarettes used per day, total duration of smoking and details of other health issues (if any) were collected. Then, the tests were performed in a standard order. All interviews were conducted in their own preferred language (Tamil, English and Telugu) to ensure good comprehension of questions and provision of precise and reliable information. The data was collected and the responses of the participants were documented. However self-reporting with a possibility of underreporting scores by the participants was one of the limitations.

Recording

Acoustic measures: The acoustic signal was recorded using PRAAT software version 6.0.32 for Windows 7 with a compatible Personal Computer (PC: Intel i5processor with a RAM of 8 Gb). In order to digitalize the voice signal, a Windows compatible 32-bit resolution sound card and recording frequency of 32, 000 Hz (Realtek HD audio) was installed. Sample frequency was 32, 000 Hz and while recording, a high frequency resolution microphone was

placed 10 cm away from the lips and was directed at an angle of ~45° towards the participant’s mouth. After a five-minute training session, each participant was instructed to phonate vowel /a/ at comfortable intensity and pitch in a soundproof chamber. Three trails were recorded and the best one was selected for final analysis. The various acoustic parameters like fundamental frequency, jitter, shimmer and harmonics to noise ratio (HNR) were analyzed by three fourth year graduate students of Speech Language Pathology. Inter rater reliability was analyzed using Cohen's kappa (κ) test and results shows excellent agreement (p < 0.001).

MPD: The participants were instructed to sustain |a| vowel sound in a single deep breath at a comfortable loudness and pitch as long as they can. The prolonged duration (in seconds) of each individual was recorded using a stopwatch and documented as a sample.

Perceptual measures: The self-introduction of the participants was recorded using a mono digital voice recorder. The samples were analyzed by three fourth year graduate students of Speech Language Pathology and scored accordingly. The interrater reliability result using Cohen's kappa (κ) test shows good agreement with p <0.001.

Self-perceptual measures: The participants are requested to Self-Administered the 5-point rating questionnaire based on the perception towards their own voice quality all over a day.

Statistical Analysis

SPSS version 25 was used to analyze the data. Descriptive statistics such as the number of data points (n), percent (%), minimum and maximum values, and arithmetic average (mean ± SD), were incorporated. Paired Sample ‘t’ test was used to compare the voice characteristics between groups. A P value of <0.05 was considered as level of significance.

Hypotheses Tested

The acoustical, perceptual, self-perceptual and aerodynamic changes are associated with an individual’s smoking product and total duration of smoking by framing hypothesis and tested with the help of paired sample ‘t’ test and descriptive statistics.

Results

The effect of filtered and unfiltered cigarette smoking in voice characteristics was determined using paired Sample ‘t’ test. The results show a significant difference in acoustic, aerodynamic and perceptual characteristics between groups. The results of analysis and comparison of acoustic characteristics of both the groups are depicted in Table 3 as follows.

Table 3: Comparison of acoustic characteristics between groups- Paired Sample ‘t’ test

Acoustic measures	Group A	Group B	t value	Statistical inference
	Mean ± SD (Min-Max)	Mean ± SD (Min-Max)		
F0 (Hz)	151.03 ± 35.29 (104.83-218.57)	132.69 ± 38.71 (80.53-213.59)	2.820	0.009<0.05 Rejected:Significant
Jitter (%)	0.42 ± 0.22 (0.19-1.30)	1.28 ± 1.16 (0.20-3.92)	3.939	0.000<0.05 Rejected:Significant
Shimmer (dB)	0.32 ± 0.17 (0.11-0.86)	1.54 ± 0.89 (0.79-4.93)	7.165	0.000<0.05 Rejected:Significant
HNR (dB)	19.86 ± 3.63 (9.94-26.01)	12.91 ± 3.81 (9.11-19.82)	6.970	0.000<0.05 Rejected:Significant

Source: Primary data (@5% level of significance)

Abbreviations: F0 (Fundamental frequency), Hz (hertz), HNR (Harmonic to Noise Ratio and Db (decibel).

H0: The smoking product do not influence the test outcomes

Acoustic Measures: The result of paired sample 't' test revealed an effect of type of cigarette on the mean F0. The unfiltered cigarette smokers (M=132.69; SD=38.71) had a lower mean compared to filtered cigarette users (M=151.03; SD=35.29).

The jitter (%) represents the variation of the fundamental frequency while measuring minor variances in the glottal pulses whereas the shimmer (dB) indicates the amplitude variation and it is related to the decrease in the coefficient of

contact of vocal folds. As per table 3, the perturbation measures also vary significantly between group, with unfiltered smokers reported with an increased jitter (M=1.28; SD=1.16) and shimmer (M=1.54; SD=0.89) when compared to filtered smokers. Similarly, in HNR, which assesses the presence of noise in the analyzed voice signal, significant decline was noted in participants using unfiltered (M=12.91; SD=3.81) cigars than filtered (M=19.86; SD=3.63).

Table 4: Comparison of Aerodynamic, Perceptual and Self-Perceptual characteristics between groups- Paired Sample 't' test

Test tools	Group A	Group B	t value	Statistical inference
	Mean \pm SD (Min-Max)	Mean \pm SD (Min-Max)		
MPD	21 \pm 1.55 (19-24)	15 \pm 3 (11-20)	7.568	0.000<0.05 Rejected: Significant
GRBAS	1.40 \pm 0.50 (1-2)	2 \pm 0.65 (1-3)	-3.154	0.007<0.05 Rejected: Significant
VHI 10	9.20 \pm 4.88 (3-18)	14.87 \pm 5.98 (3-21)	-3.179	0.007<0.05 Rejected: Significant

Source: Primary data (@5% level of significance)

Abbreviations: MPD (Maximum Phonation Duration); GRBAS (Grade, Roughness, Breathiness, Asthenia, Strain); VHI 10 (Voice Handicap Index 10)

H0: The smoking product do not influence the test outcomes

Aerodynamic analysis: The table 4 depicts a significant difference ($p=0.000<0.05$) in MPD between filtered (M=21; SD=1.55) and un-filtered cigarette consumers which shows reduced phonation duration due to consumption of unfiltered cigarette.

Perceptual analysis: An evident significant difference was noted between groups in perceptual measures. Unfiltered cigarette smokers (M=2; SD=0.65) had higher scores than filtered cigarette smokers (M=1.40; SD=0.50). This implicates the detrimental effect of unfiltered cigarettes in voice quality and strength of voice production.

Self-perceptual analysis: The VHI 10 scores showed a significant difference ($p=0.007<0.05$) between two groups. Group B individuals with the habit of using unfiltered cigarettes scored more (14.87 \pm 5.98) compare to Group A individuals (9.20 \pm 4.88) using filtered cigarettes. It exhibited that Group B individuals self-recognized their voice abnormality as severe.

Discussion

Voice production involves interaction of several systems. Evaluation of voice in a single aspect offers inadequate information regarding the status of voice quality. Thus, it should be assessed using multidimensional methods. In the present study, four discrete analysis procedures were used to examine the smokers' voice and the effect of type of smoking product. Numerous outcomes have been obtained from the former literature inspecting the effects of smoking on an individuals' voice as follows.

Acoustic voice parameters

Lower Values of Fundamental Frequency (F0)

In the present study F0 values of un-filtered smokers were lower relative to filtered cigarette smokers, significantly. This drop in F0 can be attributed to the thickening of vocal folds as a result of smoking habit (Gilbert, 1974^[28]; Guimaraes, 2005; Marcotullio, 2002^[30]; Damborenea *et al*, 1999) which is in accordance to the literatures which provide evidence on the upsurge in vocal fold volume due to edema resulted in reduction of F0. The study results add on to the literature findings that using unfiltered cigarettes can

lead to plummeting F0 values which can be due to the over exposure of smoke while using those products compared to filtered ones.

Increased perturbation values

The mean jitter and shimmer values were found to be higher in unfiltered cigarette smokers than filtered smokers. This can be perhaps due to more irregularities in vocal fold vibration caused by over exposure of smoke while using unfiltered cigarettes. The findings are in accordance to Gonzales and Carpi (2004)^[32, 31]; Chai *et al* (2011)^[33], which shows that exposure to smoke and perturbation values are proportionate to each other.

Reduced Harmonic-to-Noise Ratio (HNR)

The current study results show reduced HNR values in un-filtered cigarette smokers comparing to filtered cigarette smokers. This implicates more noise component in phonation samples of unfiltered cigarette users because of over inhalation of tobacco without proper filtering. The findings are supported by Braun (1994) who observed HNR for the smoking group as a whole was worse than for non-smokers. On the contrary, Banjara (2014)^[38] found no significant difference of HNR values in smokers as compared to non-smokers.

Aerodynamic measures

MPD, which measures lung function and vocal fold closure Ability, was found to be reduced in un-filtered cigarette smokers compared to filtered cigarette smokers. Smoking plays a vital role in minor airway obstruction and reduced lung function which leads to chronic obstructive and restrictive lung disease in adolescents (Guimaraes, 2005). The existing literatures show vivid relationship between MPD and smoking (Awan, 2007, Hansa Banjara, 2011)^[38]. The current study establishes a strong effect of type of cigarette used for smoking on MPD which is reflected by more compromised sustained phonation in unfiltered cigarette users.

Perceptual Analysis

Smoking results in a voice characterized as rough and breathy with a decreased pitch (Dworkin, 2008)^[39]. GRBAS

scores represent perceptual voice characteristics and the results implies poor voice quality in unfiltered cigarette smokers. This is in association to the current study results of acoustic analysis and can be attributed as its effect on perceptual parameters.

Self-Perceptual Analysis

A significant impact of tobacco product used for smoking is reflected in self-perception of voice through noted difference in total VHI-10 scores among filtered and unfiltered cigarette smokers, where the latter scored poorer compared to the former. This effect can be due to the profoundly affected acoustic and aerodynamic characteristics. Hence the unfiltered cigarette use also paves the way for outweighed self-reported complaints in smokers because of more severe effect on voice.

In general, use of unfiltered cigarettes have more impact on one's voice than filtered, because of wide damage, caused by large amount of smoke inhaled, in the laryngeal tissue and related structures.

Conclusion

The present study is the foremost one to precisely and comprehensively evaluate the effects of smoking product type on the vocal folds in male population using four distinct methods of analysis. Objective voice parameters assessed using acoustic voice analysis while subjective voice evaluation was done with aerodynamic measures, perceptual and self-perceptual measures. The study results emphasizes a strong relation between the smoking product type and severity of voice abnormality. The combination of voice parameters seems to suggest a feasible structural effect of toxic chemical substances on the individuals' voice. This research work may contribute a part in creating awareness of detrimental impacts of un-filtered cigarettes and highlights the need for transition from unfiltered to filtered cigarettes which decrease the prevalence of voice abnormality due to smoking. Hence, it could be concluded that smoking product had a significant impact on the voice and it should be considered as an important factor during the assessment and management of smokers' voice.

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