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Acoustic and auditory perceptual characteristics of voice in Call Center Operators

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Abstract

The present study investigated difference in voice characteristics between Call Center Operators (CCOs) reporting symptoms of vocal attrition and no symptoms of vocal attrition using acoustic and auditory perceptual measures of voice evaluation. A self-reported questionnaire was used to identify the CCOs experiencing vocal attrition symptoms and no vocal attrition symptoms. The acoustic analysis of voice performed using MDVP (Multi-Dimensional Voice Program) using phonation sample of vowel /a/. Evaluation of perceptual voice quality was made using Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) scale. No significant difference in acoustic voice parameters observed between male CCOs reporting vocal attrition symptoms and no vocal attrition symptoms, whereas, in female CCOs there was significant difference ($p = 0.023$) in NHR between two groups. However, when the acoustic parameters of CCOs (male & female) were compared with Indian normative values there were significant differences in some of the MDVP acoustic voice parameters. Auditory perceptual rating scores between the two groups (with vocal symptoms and without) overlapped considerably such that, a substantial number of CCOs who did not report of any vocal symptoms and those who did were identified as having deviancy or normalcy in the perceptual vocal parameters respectively. Eventhough acoustic and auditory perceptual measures of voice are found to be very useful in establishing voice quality impairment, the agreement between these measures and self-perceived vocal symptoms remains inconsistent and they cannot quantify the amount of vocal dysfunction experienced by an individual.

Introduction

The professional or occupational voice users are dependent on their vocal endurance and quality for their livelihood. A clear, pleasant, and well-functioning voice is a prerequisite for a professional voice user (Verdolini & Ramig, 2001; Vilkman, 2004; Casper, 2001). According to Sataloff (1991) professional voice users' lifestyle and work expose them to many dangers that may jeopardize their most valuable instrument of expression. Their voice problems can be labelled as "occupational voice disorders" as the symptoms they suffer from are likely to be caused by exposure at work. Voice problems in these professionals adversely affect their career or reduce profit for the employer, creating negative effects on their occupational performance and society (Rantala, Vilkman & Bloigu, 2002). Several assessment procedures can be used to quantify the severity of the voice problems in professional voice users viz., structural, physiological, acoustic, and auditory-perceptual analysis (Ma & Yiu, 2001). All these measures offer different perspectives in describing vocal function.

Patients' self-reporting of voice problems are subjective and depend on their moods and other intrinsic and extrinsic factors as well as their illness perception (Behrman, Sulica & He, 2004). The acoustic signal is the byproduct of phonation (the oscillation of the vocal folds as determined by aerodynamic and myo-elastic forces). Haynes and Pindzola (1998) indicated that acoustic measures may be useful in the early detection of vocal pathological conditions, even though no visually detectable lesion or tissue changes are present and there is great correspondence between physiology of voice production and acoustic measures. The deviant voice quality gives rise to acoustic "signature" affecting fundamental frequency, intensity, or quality, singly or in combination (Perkins, 1971). In the auditory-perceptual analysis of voice a listener is making a comparison between a not necessarily specified number of qualities that the listener can hear in the speaker's voice and the listener's own opinion about how these different qualities should sound in the 'normal voice' (Fex, 1992). Percep-

tual measures provide baseline information about the degree and nature of clients' voice problems and basic foundation of voice evaluation and treatment. Kent (1994) stated that "a comprehensive assessment of speech function depends upon a balance of physical and perceptual analyses. Exclusive reliance on either one alone may limit the understanding of speech impairments".

Telephone services are an example of expanding modern-day speech-related professional contexts with telephone operators/call center operators (CCOs) constituting a special group of employees whose working ability depends exclusively on their voices. The CCOs must rely solely on his/her voice without support from body language or written communication (Lehto, Laaksonen, Vilkman and Alku, 2006). The CCOs have increased vocal demands in workplace and associated vocal symptoms. Along with continuous voice use, in order to compensate for the lack of supporting communicative tools such as body language and facial expression, many call center agents speak with a voice and intonation that are unnatural and giving rise to functional disorders (Lehto, Rantala, Vilkman, Alku & Backstrom, 2003). This produces enormous vocal load on the call center operators and they face its acute manifestation as loss of voice. Several studies have identified increased prevalence of voice problems in CCOs (Jones, Sigmon, Hock, Nelson, Sullivan & Ogren, 2002; Vowels, 2004; Lehto et al., 2003, Taylor & Oates, 2004; Devadas & Rajashekhar, 2013). This brings us to the concern of early identification and treatment of voice problems in call center operators in order to reduce their severity, impact and the time needed for recovery. Thus, the present study was aimed at understanding the CCOs self-perception of vocal symptoms and acoustic and auditory perceptual characteristics of their voice as they are considered to detect early signs of vocal attrition.

Method

Participants: The study included 104 CCOs (61 males and 43 females) from five different voice based call centers from Bengaluru, who mainly used the telephone during their working hours. Their mean age was 23 years (range from 18 to 34 years) with mean working experience of 1.6 years (range from 6 months to 2.5 years). The average length of the working day was 8 hours, including 30 minutes lunch break and two 10-minute coffee breaks. All the CCOs worked in an open plan office, where individual working spaces are separated by partition walls.

Procedure

Selection of subjects for acoustic and perceptual analysis of voice: The CCOs were provided a questionnaire which included demographic details and 14 vocal attrition symptoms as given below:

1. My voice seems tired and weak when I talk or sing
2. It seems to require extra effort to talk
3. My voice is hoarse and rough
4. My voice breaks or cracks when I talk
5. My throat is uncomfortable when I talk
6. I constantly feel like I need to clear my throat
7. My throat feels dry
8. My throat feels scratchy
9. I have a burning sensation in my throat
10. I have a feeling of tightness or pressure in my throat
11. I have a choking sensation in my throat
12. I tend to lose my voice at the end of a sentence
13. I tend to lose my voice in mid-sentence
14. I frequently lose my voice completely

The CCOs were asked to indicate whether they experienced any of these symptoms by indicating 'yes' or 'no'. Further, CCOs who reported experiencing vocal symptoms were asked to indicate the frequency of their vocal symptoms such as; once in 9 months, once in 6 months, once every 2-3 months, monthly, fort nightly, weekly, or daily. Based on the questionnaire response, the samples were divided into two groups;

i) Those reporting frequent voice problems i.e., reporting two or more vocal symptoms from the list of 14 for every 2-3 months or more frequently.

ii) Those not reporting of any vocal symptoms.

Out of 104 CCOs, 36 males and 23 females reported they experienced frequent voice problems with two or more symptoms and 25 males and 20 females reported they didn't experience any vocal symptoms

Recording of Voice Sample for Acoustic Analysis of Voice: Voice samples (phonation of vowel /a/) were recorded with the participants comfortably seated in a quiet room, mostly in their company office cabins. The acoustic ambience of these rooms was quite similar across the five companies with identical furnishings: a large table, four to six chairs, closed doors, windows with curtains and centralized air conditioning. During the period of voice recording, the air conditioning unit was turned off to minimize the noise levels in the

recording room. A condenser microphone (Samson CO3U USB Multi-pattern condenser microphone) was placed at 6 cm and at 45^oangle from the participant's lips. The recording was done on the hard disk of a personal laptop computer (IBM ThinkPad) installed with a Wave Surfer recording software. The speech sample was recorded at a sampling rate of 44,100 Hz, bit rate of 256 kbps and stored in the hard disc in *.wav format. The participants were asked to phonate vowel /a/ at their comfortable pitch, loudness and duration (at least 5-6secs). Each participant was given two to three trials prior to actual recording.

Acoustic Analyses: Multi-Dimensional Voice Program (MDVP; model 5105, Kay Elemetrics Corp.) was used for the acoustic analysis of the recorded samples. The initial and final parts of the phonation of vowel /a/ were eliminated and a 3 sec signal (the central part of the phonation being the most regular, least affected by onset and offset of the vocal signal) was captured and analyzed for the MDVP acoustic parameters.

Recording of Voice Smples for Perceptual Analysis of Voice: Evaluation of voice quality was made using Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) scale. According to the specifications of CAPE-V, three different tasks were audio recorded using similar settings for the acoustic analysis. The first task was recording the phonation of lax and tense vowels (/a /& /i/) three times, each at a steady and comfortable pitch and loudness level for 7 - 8 secs. The entire phonation sample was used for the perceptual analysis. The second task was reading of six English sentences with different phonetic contexts, and described by Kempster, Gerratt, Abbott, Barkmeier-Kraemer, & Hillman (2009) as: (1) *The blue spot is on the key again* (2) *How hard did he hit him*? (3) *We were away a year ago* (4) *We eat eggs every Easter* (5) *My mama makes lemon* (6) *Peter will keep at the peak.* The third task was recording of natural conversational speech of around 20 seconds. The subjects were asked standard interview questions concerning their education, work and family. Model for each task was provided before recording the sample along with one or two trials. The samples were stored in Microsoft Windows wave format (*.wav) and copied in a single track with an interstimulus interval of 5 seconds using Adobe version 3.0. The recorded samples were then randomized (samples of those reporting frequent voice problems and no voice problems) and copied to a CD.

Procedures of Auditory Perceptual Evaluation: Three qualified speech language pathologists (Faculty at the Department of Speech and Hearing) with more than five years of experience, good knowledge of English language and normal hearing threshold served as judges. The recorded speech samples were played using HP Desktop Pentium IV Computer, in a sound treated room using Adobe Audition through loudspeakers (Tannoy, 034856) at a consistent and comfortable intensity level with the listener seated 3ft away from the loudspeaker. A separate session was arranged for each judge. Each judge performed the perceptual evaluation in one session (one day) with pauses in between suiting their convenience and with no limit on the number of times they could listen to the recorded samples. The judges rated the voice samples using CAPE-V rating form by placing the tick mark on the visual analog scale. In case of discrepancies in voice quality across tasks, they were asked to put tick marks with task number and leave the line unlabeled with a single tick mark if there was no difference across the tasks. The distances of markings made by the judges on the visual analog scale (CAPE-V scoring sheet) were measured physically from left end of the scale using a measuring scale, thereby relating the results in a proportion to the total 100 mm length of the line to describe the degree of deviancy. In the present study, the 100mm visual analog was arbitrarily divided in to four sections in order to understand the severity of the perceived vocal parameter. The average rating falling within the range of 0 - 9mm was considered as of normal voice quality; within the range of 10 - 39mm, as mild deviancy; 40 - 69mm, as moderate deviancy and more than 70mm, as severe deviancy.

Reliability: Inter and Intra-rater reliability of perceptual evaluation by the three judges for different tasks was analyzed using Intra-class Correlation Coefficients (ICC). Inter-rater reliability was evaluated by comparing the perceptual ratings of severity of the voice samples among the three listeners. Intra-rater reliability of the judgment was evaluated for the 15(10%) voice samples which were rated by all the three listeners for the second time in a separate session.

Statistical Analyses: Mann-Whitney U test used to compare the different acoustic parameters between the two groups of CCOs; those reporting frequent vocal attrition symptoms and those not reporting frequent vocal symptoms. It was used to estimate the significance of changes in acoustic parameters in relation to experiencing frequent vocal symptoms and not experiencing vocal symptoms. One sample t-test used to compare the acoustic parameters of CCOs with the Indian normative data base for MDVP acoustic parameters. Intra-class Correlation Coefficient (ICC) used to measure the inter and intra rater reliability of the perceptual analysis ratings. SPSS software version 15 was used for the analyses of all the data. $p < 0.05$ was considered as statistically significant.

Results

The most commonly reported vocal symptoms by the CCOs participated in the present study (both males and females) were: tiring of voice while talking or singing, effortful voice or needs extra effort to talk, hoarse or rough voice, frequent clearing of throat, dryness of the throat, feeling of tightness or pressure in the throat, and loss of voice at the end of the sentence. Among the 59 (36 males and 23 females) CCOs who reported to have frequent vocal symptoms, 22 males and 11 female CCOs reported that they experienced these symptoms either daily or once in a week.

To determine the acoustic parameter(s) which could be sensitive indicators of differences between male and female CCOs who reported of frequent vocal symptoms and those who did not, the median values of 25 MDVP acoustic parameters (fundamental frequency related measures, frequency perturbation related measures, amplitude perturbation related measures, noise and tremor related measures) were calculated for both the groups. A Mann-Whitney U test was performed to determine if there was a significant group difference. Even though the analysis by MDVP provided information on 33 acoustic parameters, only 25 acoustic parameters were included in the present study; the following acoustic parameters were excluded for the reasons stated: the parameters that analyzed voice breaks (NVB and DVB), unvoiced segments (NUV and DUV) were excluded as their values were zero; number of sub-harmonic segments (NSH) and the degree of sub harmonics in the acoustic signal (DSH) were excluded as there were no subharmonics present in the (majority) analyzed data (value of zero).

The results of Mann-Whitney U test did not reveal any significant difference between two groups (CCOs who reported vocal symptoms and who did not) of male CCOs, whereas, in females, only the parameter of NHR was significantly ($p = 0.023$) different between the two groups.

Comparison of the Acoustic Parameters of the CCOs with Indian Norms: To see whether the obtained acoustic parameters of CCOs in the present study were within the available normative range, the obtained data was compared with the only published Indian norms (Hema, Sangeetha, & Pushpavathi, 2009) for MDVP acoustic parameters using one way independent t-test. As the acoustic analysis for the CCOs reporting of frequent vocal symptoms and those not reporting did not reveal significant differences, barring NHR in the female CCO groups, the data was combined for the two groups of male and female CCOs and compared with the normative acoustic values. Table 1 and 2, show the comparison of mean and SD of acoustic parameters of CCOs and Indian normative values for male and female CCOs respectively.

As shown in Tables 1 and 2, some of the MDVP acoustic parameters of CCOs (both genders) were significantly deviant from normative values. This deviancy was clearly evident in frequency and amplitude perturbation parameters.

Auditory Perceptual Analyses: The purpose of the perceptual analysis was to identify any differences in the auditory perceptual vocal quality between CCOs who reported of frequent vocal symptoms and those who did not, using CAPE-V auditory perceptual analysis scale. Three experienced Speech Language Pathologists rated their voice quality across the six vocal parameters: overall severity, breathiness, roughness, strain, pitch and loudness.

Inter Rater Reliability: The ratings given by each listener (judge) for each subject for three different tasks (phonation, sentence reading, and spontaneous speech) were measured physically using a measurement scale. Further, these scores were compared across the three judges (for different tasks) for inter rater reliability using Intra-class Correlation Coefficient (ICC) method. The ICC inter-rater reliability co-efficients ranged between 0.73 to 0.89 across the different perceptual parameters between the three raters.

Intra Rater Reliability: Out of 104 recorded voice samples, fifteen (15%) were rated after a week for the second time by all the three listeners to evaluate the intra rater reliability. Intra rater reliability on ICC ranged between 0.80 to 0.92 for all the perceptual parameters among the three judges and was accepted as an indication of each rater maintaining internal consistency in making judgments of voice qualities.

Voice quality ratings: To enable statistical analysis of listeners' judgments, ratings from the three judges were averaged for each parameter of each task (phonation, sentence reading, and spontaneous speech). The average perceptual ratings of the three judges for 104 voice samples (both groups) ranged between 0 to 38mm on the visual analog scale across the different tasks for different perceptual parameters. It was interesting to observe that the ratings on the visual analog scale for majority were between 0 - 9 mm indicating normalcy and for the rest, between 10 - 39mm indicating mild deviancy (Table 5).

The data presented in Table 3 has been discussed with reference to the different perceptual parameters based on the perceptual ratings obtained in the three different tasks. An overview of Table 3

Table 1: Comparison of acoustic variables between male CCOs and the Indian norms for males

Acoustic Parameters	Mean Value of male CCOs (SD)	Mean Normative value of males (SD)	P value
Fundamental Frequency Information Measurements			
Average F0	133.42 (22.07)	131.62 (12.72)	0.527
Mean F0	133.39 (22.07)	130.17 (14.15)	0.259
Average Pitch Period	7.67 (1.12)	7.65 ((0.69)	0.870
Highest F0	139.89 (22.57)	136.51(12.43)	0.246
Lowest F0	127.78 (21.91)	125.49 (10.83)	0.416
Standard deviation F0	1.67 (0.75)	1.29 (0.35)	<0.001
F0 Range	2.62 (1.24)	2.42 (0.80)	0.206
Frequency Perturbation Measurements			
Absolute Jitter	69.15 (52.07)	53.98 (22.90)	0.061
Jitter percent	0.97 (0.78)	0.73 (0.35)	0.250
Relative average perturbation	0.58 (0.49)	0.44 (0.21)	0.035
Pitch perturbation quotient	0.56 (0.46)	0.43 (0.20)	0.027
Smoothed Pitch Perturbation Quotient	0.79 (0.44)	0.63 (0.20)	0.004
Fundamental frequency variation	1.28 (0.65)	0.98 (0.26)	0.001
Amplitude Perturbation Measurements			
Shimmer in dB	0.30 (0.13)	0.29 (0.06)	0.482
Shimmer percent	3.46 (1.53)	3.33 (0.72)	0.519
Amplitude perturbation quotient	2.64 (1.04)	2.46 (0.49)	0.172
Smoothed Amplitude perturbation quotient	4.69 (1.62)	3.98 (0.90)	0.001
Peak to peak amplitude variation	10.53 (4.70)	10.13 (2.95)	0.506
Noise and Tremor Evaluation Measurements			
Noise to harmonic ratio	0.14 (0.30)	0.14 (0.07)	0.336
Voice turbulence index	0.04 (0.01)	0.03 (0.00)	<0.001
Soft phonation index	26.46 (16.31)	17.59 (10.82)	<0.001
Tremor related measures			
F0-tremor intensity index	0.31 (0.18)	0.22 (0.10)	0.001
Amplitude tremor intensity index	3.23 (1.90)	2.86 (1.55)	0.195
F0 Tremor frequency	3.75 (1.39)	3.56 (1.48)	0.328
Amplitude tremor frequency	4.07 (1.90)	4.19 (1.53)	0.672

Mean and standard deviation for acoustic variables for male CCOs and Indian normative for male subjects. Boldface values indicate statistical significance.

indicates that the ratings of the perceptual parameters differed between the three tasks (phonation, sentence reading & spontaneous speech) across genders reporting of vocal symptoms and no symptoms. It was observed that, the perceptual parameters differed between the tasks with greater difference between task 1 (phonation) and tasks 2 & 3 (sentence reading & spontaneous speech) with no difference between tasks 2 & 3. That is, the task of phonation reflected greater deviancy among the evaluated perceptual parameters than the other two tasks of sentence reading and spon-

Table 2: Comparison of acoustic variables between female CCOs and the Indian norms for females

Acoustic Parameters	Mean Value of female CCOs (SD)	Normative value of females (SD)	P value
Fundamental Frequency Information Measurements			
Average F0	222.24 (20.79)	228.26 (15.52)	0.065
Mean F0	222.18 (20.20)	228.52 (15.65)	0.052
Average Pitch Period	4.50 (0.47)	4.39 (0.30)	0.051
Highest F0	236.74 (28.76)	237.62 (17.28)	0.844
Lowest F0	210.63 (21.95)	219.77 (14.45)	0.059
Standard deviation F0	3.01 (1.80)	2.21 (0.87)	0.005
F0 Range	3.06 (2.13)	2.34 (0.57)	0.030
Frequency Perturbation Measurements			
Absolute Jitter	51.84 (29.66)	42.77 (24.15)	0.051
Jitter percent	1.18 (0.73)	0.99 (0.55)	0.094
Relative average perturbation	0.71 (0.44)	0.58 (0.32)	0.049
Pitch perturbation quotient	0.69 (0.44)	0.56 (0.30)	0.069
Smoothed Pitch perturbation quotient	0.79 (0.40)	0.60 (0.28)	0.003
Fundamental frequency variation	1.36 (0.83)	0.95 (0.38)	0.002
Amplitude Perturbation Measurements			
Shimmer in dB	0.32 (0.14)	0.28 (0.04)	0.051
Shimmer percent	3.66 (1.53)	3.14 (0.65)	0.031
Amplitude perturbation quotient	2.60 (1.06)	2.19 (0.28)	0.016
Smoothed Amplitude perturbation quotient	4.60 (1.16)	2.91 (0.43)	<0.001
Peak to peak amplitude variation	12.25 (4.77)	8.82 (2.10)	<0.001
Noise and Tremor Evaluation Measurements			
Noise to harmonic ratio	0.13 (0.03)	0.12 (0.06)	0.001
Voice turbulence index	0.04 (0.01)	0.04 (0.03)	0.278
Soft phonation index	20.54 (10.17)	14.47 (4.60)	<0.001
Tremor related measures			
F0-tremor intensity index	0.30 (0.25)	0.14 (0.07)	<0.001
Amplitude tremor intensity index	3.95 (1.61)	1.88 (1.89)	<0.001
F0 Tremor frequency	3.95 (1.16)	4.10 (1.64)	0.292
Amplitude tremor frequency	2.79 (1.12)	2.64 (1.82)	0.089

Mean and standard deviation for acoustic variables for female CCOs and Indian normative for females. Boldface values indicate statistical significance ($p< 0.05$).

taneous speech. In other words, deviancy from the normal vocal quality has been greatly identified during the phonation task. Other than parameters shown in the table 3 the listeners also rated the CCOs pitch, loudness and resonance characteristics. All the CCOs were rated to have adequate loudness and resonance whereas, two males and six females were rated as having lower pitch and six males and one female, higher pitch during phonation. In general, the range of perceptual rating scores between the two groups (with vocal symptoms and without) overlapped considerably such

Table 3: Number of CCOs from both genders (with and without vocal symptoms) perceptually identified normal or deviant voice quality

Perceptual Parameters		Males				Females			
		With vocal symptoms (n=36)		Without vocal symptoms(n=25)		With vocal symptoms(n=23)		Without vocal symptoms(n=20)	
		Normal	Mild	Normal	Mild	Normal	Mild	Normal	Mild	Normal
Overall severity	Task 1	21	15	17	08	14	09	14	06
	Task 2	33	03	21	04	21	02	18	02
	Task 3	33	03	21	04	21	02	18	02
Roughness	Task 1	18	18	18	07	14	09	13	07
	Task 2	23	13	17	08	21	02	19	01
	Task 3	23	13	17	08	21	02	19	01
Breathiness	Task 1	20	16	15	10	10	13	08	12
	Task 2	32	04	20	05	14	09	12	08
	Task 3	32	04	20	05	14	09	12	08
Strain	Task 1	26	10	18	07	13	10	11	09
	Task 2	35	01	22	03	22	01	18	02
	Task 3	35	01	22	03	22	01	18	02

Rating of normal or mild deviancy in voice quality for the perceptual parameters among male and female CCOs across the different tasks. Task 1; phonation, Task 2; sentence reading, Task 3; spontaneous speech.

that, a substantial number of CCOs who did not report of any vocal symptoms and those who did were identified as having deviancy or normalcy in the perceptual vocal parameters respectively.

Discussion

The purpose of comparing the acoustic parameters of voice between the two groups (those who reported of frequent vocal symptoms and those who did not) was to determine whether they can differentiate the two groups on presumption that, acoustic measures help understand the physiology of vocal mechanism, even when no visually detectable lesion or tissue changes are present (Colton and Casper, 1996).

For this purpose, a wide set of acoustic parameters measured by the MDVP analysis from a single vocalization was used. It was further presumed that, the more extensive the parameters used, the more likelihood of finding the difference. In the present study, no significant differences were observed between two groups (CCOs reporting vocal symptoms and not reporting vocal symptoms) across different acoustic parameters barring H/N ratio among the female CCOs suggesting there is an incomplete glottic closure during phonation in female CCOs, which is significantly higher in the females who reported of vocal symptoms. Based on the findings of the current study, it can be presumed that, both the groups have either normal vocal fold physiology or affected slightly. Further, it can also lead to the assumption that, the reporting of vocal symptoms depends on individual sensitivity and acoustic parameters may fail to derive any association between self-reported voice symptoms.

Hence, to be more comprehensive, the present study, compared the acoustic parameters of CCOs (combined from those reporting of voice problems and those who did not) with normative values of adult Indian population (Hema et al, 2009).The results indicated significant difference in few of the acoustic parameters compared to normative values; standard deviation in F0 and F0 range, some of the frequency perturbation measures (PPQ, RAP, SPPQ, and vF0) and amplitude perturbation measures (sAPQ, vAm, Shim%, APQ), noise related measures (NHR, VTI, SPI), tremor related measures (FTRI & ATRI).

A significant increase in standard deviation in F0, F0 range, frequency and amplitude perturbation measures leads to the assumption that, there is some variation in periodicity of vocal fold vibrations or unable to maintain the regular pattern of vocal fold vibration. F0 range is the difference between the highest and lowest F0 voice in a sample which could sometimes be affected based on the extreme values and distorts the interpretation. However, there are no supportive studies for the hypothesis that pitch range increased in CCOs. Further investigation is needed to determine if this is an artifact of CCOs vocal training specific to their function. Increase in the perturbation parameters exceeding the threshold of normality indicate the early signs of some pathological changes present on the vocal fold or there may be in coordination between laryngeal, respiratory and elastic forces altering the sub-glottic pressure owing to incomplete glottis closure (Titze, Horii, & Scherer, 1987; Higgins & Saxman,1989). Similarly, increased noise measures indicate additive noise content in the voice signal (Titze, 1995) and significant increase in tremor related measures indicate altered tension in the vocal folds (Baken & Orlikoff, 2000; Shao, Mac Callum, Zhang, Sprecher& Jiang, 2010). However, the contribution of these acoustic measures to identify the specific abnormalities of the glottal function in general is not clear (Baken & Orlikoff, 2000) as several acoustic parameters are sensitive to several physiological parameters of the vocal folds. Hence, it is difficult to predict the pathological changes associated with the CCOs depending on these measures.

Among the different perceptual vocal attributes listed in the CAPE-V (roughness, breathiness, strain), higher number of male CCOs were rated to have roughness while higher number of female CCOs were rated to have breathiness as the common vocal quality alteration. Physiologically, roughness is associated with irregular vocal fold vibration and breathy voice corresponds with hypoadduction of the vocal folds. This finding is also supported by the presence of significantly higher NHR values in female CCOs who reported voice problems. The results of the present study is supported by the findings of Munoz, Mendoza, Fresneda, Carballo & Lopez (2003), where given the two voices of different F0 with the same aperiodicity, the voice with lower F0 will be judged more rough than the voice with higher F0.

In the auditory perceptual analysis, the range of scores on the visual analog scale (CAPE -V) between the two groups overlapped considerably, such that, a substantial number of CCOs who did not report of any vocal symptoms were identified to have deviancy in perceptual vocal parameters. In addition, many CCOs reporting of vocal symptoms were not perceived to have deviancy in vocal quality. However, most of them were identified as having normal voice quality from both the groups with good inter and intra rater reliability. The present study finds support from Sapienza & Woodson (2009), that, self-reporting of voice problems is found to be subjective and depends on the person's mood and other intrinsic and extrinsic factors as well as their illness perception. Listeners quantify the quality (comparing with concept of normalcy) and severity of vocal function or voice problems. That is, the auditory perceptual evaluation of a person's voice means that a listener is making a comparison between a not necessarily specified number of qualities that the listener can hear in the speaker's voice and the listener's own opinion about how these different qualities should sound in the "normal voice" (Fex, 1992). That is, auditory perceptual evaluation of voice is dependent on the auditory perception of acoustic elements of phonation that characterizes an individual speaker. Thus, it is an interaction between the acoustic speech signal and a listener's perception of that signal. However, auditory perceptual evaluation cannot measure the impact of the voice disorder on the individual. The impact of the voice problem depends on how the individual perceives responds and adapts to the problem, and not on its severity (Yiu, 2002).On the other hand, self-reported voice problems are often based on the magnitude of the voice related problems experienced by the participants in their daily activities, and the importance that they place on those problems. Another plausible reason for the differences could be that CCOs report the prevalence of symptoms over a longer time span while the clinicians evaluate the voice samples during single moment of the time.

Further, it was observed that, across the speakers, with respect to different tasks (phonation, reading and spontaneous speech), perception of sustained vowels was judged to be more severe than sentence reading or spontaneous speech. That is, many of the CCOs were rated to have mild deviation in their voice quality during phonation tasks and were rated as normal during sentence reading and spontaneous speech. Similarly, very few CCOs (n=15) were rated to have either mild low or high pitch during phonation tasks or normal pitch during reading and spontaneous speech tasks with normal loudness and resonance across the tasks. This is in accordance with the findings of earlier studies (Wolfe, Cornell & Fitch, 1995; Revis, Giovanni, Wuyts & Triglia, 1999), that normal speakers' voice was rated to be more dysphonic during sustained phonation than continuous speech. Subjects change their voices for sustained vowels especially during the onset of phonation. Hence, when a complete sustained vowel is used for perceptual evaluation (including both onset and offset part of vowel), there may be over estimation of the severity of the vocal dysfunction. This could be the possible reason for the difference in rating the voice quality in phonation and speech tasks of the present study, which has used complete sustained vowel for the perceptual analysis. Along with this, other reasons for the discrepancy are the perception of pitch during phonation and speech tasks by the listeners failing to perceive the mild deviation in the pitch (high or low) during reading or speech with their attention shifted to non-vocal source of information (e.g., dialect variation, rate of speech etc) (deKrome, 1994), as well as variation in prosodic features (stress and intonation) within the connected speech segment.

Hence, it is unlikely that a correlation exists between self-perceived vocal symptoms and the acoustic and auditory perceptual measures (Kent, 1994). This was found true in the present study where, there were significant overlap between acoustic and auditory perceptual parameters of CCOs with and without self-reporting of vocal symptoms. This leads to the question of whether the CCOs who reported of vocal symptoms would have any organic changes in the vocal folds. Further research by visualization of larynx of these two groups could provide the answer. Literature regarding professional voice users indicates that occupational voice disorders are very common and constitute a real threat to the functionality and working ability of these individuals.

Conclusions

Since voice is multi-dimensional, it can be characterized by acoustic, perceptual, physiological and

self-reported aspects. The present study attempted to understand the voice characteristics of CCOs using self-reported questionnaire along with acoustic and auditory perceptual measures. The results of the current study support the findings in the literature that there is a poor agreement between self-perceived vocal symptoms and acoustic measures and auditory perceptual rating of voice quality. In the present study, the acoustic and auditory perceptual measures of voice quality failed to differentiate CCOs experiencing vocal symptoms or not. However, acoustic voice parameters when compared with normative values, significant differences observed in many of the acoustic parameters. This indicates that, CCOs are at greater risk of developing voice disorders. Hence, these symptoms experienced by the CCOs could be considered as early signs of vocal attrition even though not very severe in their form. The current study hence projects and reiterates the need to educate CCOs on early identification and management of vocal symptoms.

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