AN ATTEMPT TO EXPLORE PROLONGED EFFECTS OF AIR CONDITIONER ON VOICE QUALITY: A PRELIMINARY STUDY

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CERTIFICATE

This is to certify that the dissertation entitled **"*An Attempt to Explore Prolonged Effects of Air Conditioner on Voice Quality: A Preliminary Study*"** is a bonafide work submitted in part fulfillment for the degree of ***Master of Science*** (***Speech – Language Pathology***) of the student Registration No. 16SLP024. This has been carried out under the guidance of a faculty of the institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysore
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CERTIFICATE

This is to certify that the dissertation entitled "***An Attempt to Explore Prolonged Effects of Air Conditioner on Voice Quality: A Preliminary Study***" has been prepared under my supervision and guidance. It is also certified that it has not been submitted earlier to any other University for the award of any Diploma or Degree.

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DECLARATION

This dissertation entitled "***An Attempt to Explore Prolonged Effects of Air Conditioner on Voice Quality: A Preliminary Study"*** is the result of my own study under the guidance of Dr. K. Yeshoda, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any Diploma or Degree.

Mysore, Registration No: 16SLP024
May 2018

DEDICATION

This work is dedicated to

PAPPA, MAMMA, ABHIMANYU

&

MY GUIDE

ACKNOWLEDGMENT

When any significant work is accomplished, the credit never lies on the back of one single person. Many people play the role immediate support but some can be involved more in the form of the moral support which does play more crucial role.

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Chapter I

Introduction

As unique as the signature, is the voice of an individual - be it professional voice user or a non professional voice user. Any small complication in voice for a non professional voice user is not a major factor (Koufman & Isaacson, 1991), but it definitely bothers him/her while carrying out day-to-day schedules. Among the factors that influence and could have a contribution for the voice disorders include broadly- (i) Personality related factors; (ii) Environmental factors; (iii) Health and Physiological factors and (iv) Phonatory factors (Child,1991). Temperature and relative humidity are amongst the environmental factors that play a role in contributing to the voice disorders. One of the artificial, comfort-level-increasing luxury products are air conditioners, which controls the relative humidity as well as temperature which in turn makes an environment comfortable for the individual (Morton, 2015).

Air conditioners are sensitive to changing level of humidity which leads to increased moisture in winter and the drier conditions in summers, which help people, feel more comfortable (Cooper, 2002). Cold air has a small capacity for moisture while hot air has a large capacity of moisture. Low humidity causes the generalized drying of the laryngeal membranes which could also be seen in the beginning of the winters. This lack of lubrication leads to disturbance of normal vocal functions (Child,1991). Boone (1983) has continually stressed the importance of proper humidification of vocal folds for its normal functioning. Adequate humidity has been highlighted in the voice literature and vocal performers have addressed its importance for many years. Stone (1982) has also emphasized the importance of laryngeal lubrication as well as a need to carefully monitor and restrict agents that act as dehydrates in those individuals experiencing vocal difficulty. Humidity plays a role in altering the hydration systems of the vocal folds and the viscosity as well.

Types of Hydration and Viscosity

Vocal folds have covering of a thin liquid layer (Nakagawa, Fukuda, Kawaida, Shiotani & Kanzaki, 1998). This liquid is a physical and biochemical barrier that protects the underlying tissue from inhaled particulates and pathogens (Leydon, Sivasankar, Falciglia, Atkins & Fisher, 2009). Two systems of hydration govern the responsibility of lubricating the vocal system namely, the Systemic hydration and Superficial hydration. Systemic hydration refers to fluid within body and vocal fold tissue. Intake of caffeinated and alcoholic beverages, medications are the factors that affect systemic hydration.

Superficial hydration is the fluid lining the vocal fold surface and laryngeal lumen. Humidity, water consumption and nasal breathing resulting in humidified air are the factors which when altered would result in effect on the superficial hydration (Leydon et al., 2009; Leydon, Wroblewski, Eichorn & Sivasankar, 2010). An emphasis on the importance of superficial hydration was put forth by simulation created by applying synthetic fluids on the vocal folds - which would either dehydrate or hydrate the vocal folds; resulting in an reduction in amplitude of vocal fold motion in the condition leading to dehydration (Nakagawa et al., 1998) and transient increase in vocal fold contact time in hydrating condition (Ayache, Ouaknine, Dejonkere, Prindere & Giovanni, 2004). The study had concluded that the superficial dehydration had adverse effects on the vocal fold vibratory function.

Viscosity is one of the biomechanical properties of the vocal folds along with other two being the mass and stiffness. It is the measure of resistance to deformation of the vocal fold tissue – which is increased by hydration and decreased by drying (Verdolini, Titze & Fennell, 1994). Higher viscosity means higher subglottal pressure will be required to initiate vocal fold vibration. Hence, the viscoelasticity of the vocal folds significantly affects their vibratory characteristics. Higher viscosity, as a results of dehydration of the vocal folds, might translate greater energy loss in the form of heat, and a higher phonation threshold pressure (Sandage, Connor & Pascoe, 2014). The objective measures have highlighted a variation in physiology; similarly, the perceptual complaints of the individuals would also play a role in understanding the effect of dehumidified environment on an individual's quality of life.

Effects of AC on Vocal System and Voice

An environment which is completely treated for humidity, is a well known and quite in-demand condition for most of the urban population in the today's world. Air conditioners bring this change in temperature by thus making the environment more productive and appealing. Fang, Wyon, Clausen and Fanger (2004) have highlighted that the air which is cool and dry is perceived more fresh and acceptable than warm and humid which is stuffy and unacceptable, in spite of being clean. Dissatisfaction level from air quality ranges from 20-70% amongst the customers, depending on climatic region (Wargocki, Wyon and Fanger, 2000b). Thus having air conditioners has become a primary need in lot of working areas. While the need of the comfortable environment becomes a necessity and the demand for the same has always had a rising graph; the need arises to observe the possible potential effects of the air conditioned environment on any aspect of health of the human being.

Air inhaled is humidified and made warm by the lining of the nasal tract; which thus ensures that the air reaching the vocal tract and lungs are humidified and warmed up to certain extent. The immediate effects of the air conditioned environment could be seen on the upper respiratory tract; as they form a direct encounter with the dry air. Graudez, Oliveria, Tribess, Mendes, Latorre and Kalil (2017) revealed the individuals had nasal symptoms, persistent cough, sinusitis symptoms and building related worsening of symptoms with working in air-conditioning buildings through a self administered questionnaire. While they concluded that artificial air conditioning is a matter of concern for respiratory symptoms in cities with hot and humid climate.

The indication of effects observed in respiratory systems were further extended to the laryngeal level and brought to notice by the work of Everett, Blasi & Robert (2015) along with Miri, Barthelat, Mongeau, (2012).The effects of breathing cold air on the vocal tract and the larynx have been supported by numerous studies of those active outdoors in frigid contexts (Makinen, Juvonen, Jokelainen, Harju, Peisto, Bloigu & Hassi, 2009; Sue- Chu, 2012). Hence, inhalation of dry air could cause the dehydration of vocal fold lining; and would lead to disturbances in vocal fold physiology and results in definite effects on phonation. One of the many reason for this could be reduced viscosity of laryngeal mucosa and associated alterations to the cohesive forces at work during the contact portion of vocal fold oscillations.

Till date literature has kept the point of focus for such effects on professional voice users, specifically, singers. The emphasis was given on their working environment and hydration levels. Hydration treatment has always been a choice of treatment since long time. Aerodynamic measure, acoustic measures and even perceptual discomfort when studied had revealed significant relations with the altered conditions in terms of humidity or hydrations.

Need for the study

The effects on voice is perceived; while in the past, it has either, always revolved around professional voice users or around the analysis of the immediate effects on the voice quality as subjected to temperature change. Little effort has been done to see a prolonged or long standing effect of artificial ambient temperature regulated manually on voice quality. This necessitates a need to explore the effects of artificial ambient temperature regulated manually on the vocal health. Results of such studies may help in identifying early signs of the vocal cord pathology.

Aim

To explore the prolonged effects of exposure to air conditioned environment on voice parameters of healthy individuals.

Chapter II

Review of Literature

One of the artificial, comfort-level-increasing luxury products are air conditioners, which controls the relative humidity as well as temperature which in turn makes an environment comfortable for the individual (Morton, 2015). Though, the environment is work friendly, its effects are evident on respiratory system that shares a same mucous lining throughout the vocal tract (Zemlin, 1982) so, a variation in normal physiology of the vocal tract could be expected. Aerodynamics and acoustic measures would be efficient objective ways to understand the voice quality of the individuals exposed to dehumidified conditions formed by air conditions.

Manuscript & Pet (2007) studied the effects of viscosity of the vocal folds. The canine larynges were loaded with liquids of different viscosity – thin liquid, nectar and honey; which stimulated the condition of vocal fold mucosa viscosity variation. The acoustic parameters were studied which indicated that fundamental frequency remained unaltered when measured at baseline: thin liquid, nectar and honey loaded conditions; while perturbation measures increased but were not consistent indicator to comment on effect of the the level of viscosity on acoustic parameters (Murugappan, Boyce, Khosla, Kelchner & Gutmark, 2010; Ramig, Scherer, Klasner, Titze and Horii, 1990).

The visco-elasticity variations bring about changes in the acoustic parameters as well. Hemler, Wieneke & Dejonckere (1997) explored the acoustic parameters after the short duration of exposure of an individual to different relative humidity air conditions like, dry air, standard room and humidified air. The conditions lasted for 10 minutes along with mouth inhalation so that the nasal humidification is ruled out. After this the individual had to sustain the phonation /a/. The acoustic analysis of the phonation /a/ was done post exposure. The participants' feedback revealed that they experienced discomfort and unpleasant feeling only during the dry condition for breathing. Further findings suggested that the perturbation parameters had increased and more specifically, the Absolute Jitter, Relative Jitter and PPQ showed significant increase in the dry air condition. Reportedly, the Shimmer values had increased in the dry air exposure while they did not show significant difference in the standard and humidified air conditions. The perturbations are the measures that show variations due to glottal resistance variation and even with the presence of the mass lesions in the vocal folds (Teixeira, Oliveira and Lopes, 2013).Whereas, noise related parameters (noise to harmonics ratio) did not show any significant results.

They concluded by stating that the human voice is very sensitive to decrease in relative humidity of inhaled air. A short provocation with dry air showed a significant increase in perturbation measures. Also in some cases, the perturbation parameters increased 50% after an exposure of 10 min of inhalation of very dry air. Thus, putting forth that the perturbation measures could be sensitive to the exposure for air conditioned environment.

Subglottic pressure could be an indicative of viscosity. A study Chan & Titze (2006) indicated that higher viscosity means higher subglottal pressure will be required to initiate vocal fold vibration. Higher viscosity, could result from dehydration of the vocal folds, translates greater energy loss in the form of heat, and a higher phonation threshold pressure. Baken and Orlikoff (2010) postulated that the vocal F0 varies as a function of subglottal pressure, which in turn, is a major physiologic determinant of vocal intensity. Else wise, intense speech could also show higher F0 values which could also be attributed of personality factors and has a range of around 30 Hz (Aronson and Bless, 2009).

Aerodynamic measures of Maximum Phonation Time (MPT) give the degree of laryngeal dysfunction and especially when inadequate glottal airway resistance is suspected (Hirano, 1989). Another measure to give insight about the respiratory and laryngeal system would be s/z ratio. A definite change in MPT and s/z ratio could be expected as the visco-elastic properties of the vocal folds would be altered. The effect of hydration was studied by Wyk, Cloete, Hattingh, Linde and Geertsema (2016) in future professional vocal performers with a pretest and post test design where two groups were compared with a hypohydrated and hydrated condition and their relation between the acoustic and perceptual parameters were observed. MPT of vowel /a/ and MPT of /z/ increased in duration within the hydrated condition. But the findings of Neiman & Edeson (1981) along with Soman, (1997) emphasizes that the importance of practice and attention plays major roles in eliciting MPT and s/z ratio values.

The MPT and s/z ratio have been studied extensively in the literature for professional voice users and hydration results related to the same. As this present study intended to study the effects on air conditioned environment which has a dehydrating effect on the laryngeal structures along with other systems; the measures of the MPT and s/z would give important information about the glottal efficiency and breathe support.

The effects were notably seen in the aerodynamic and acoustic parameters of voice. Prolonged air conditioned environment are one of the factors that leads to dehydration. The immediate effects of hydration and humidity reveal a definite impact on the vocal physiology; thus a long-standing impact, if any, would also be of interest to the speech language pathology, especially in idiopathic etiological conditions.

Objective

- To explore the voice characteristics of individuals exposed to air conditioned environment for a prolonged period.
- To compare with a control group for similarities/ differences.

CHAPTER III

Method

Participants

The participants of the study were divided into 2 groups- experimental group and control group. All the participants had a minimum of higher secondary education and were non- professional voice users. All participants did not report of any speech/ language/ hearing/ neurological/ psychological problems were screened with an informal checklist containing a total of 10 questions regarding their lifestyle, general history of previous medications for any endocrinal disorders, as well as surgeries, if any, to ascertain the inclusion criteria.

Experimental group:

Female participants in the age range 26-45 (34.25 / 5.01) years with more than 4 years of working in AC environment and those who work for more than 6 hours in a day formed the participants. They were all non professional voice user (PVU)

Exclusion criteria:

- Any earlier history of voice problems/ vocal tract surgery
- If participants were of level 1 or level 2 professional voice user
- If participant was having her menstrual cycle
- If participant was pregnant
- If participant was on any thyroid medication

Control group:

Female participants within age range 28-45 (34.28 / 4.43) years formed the participants of this group. They worked in firms which did not have AC environment. They were also non professional voice users.

Exclusion criteria:

- Any earlier history of voice problems/ vocal tract surgery
- If participant was level 1 or level 2 professional voice user
- If participant was having her menstrual cycle
- If participant was pregnant
- If participant was on any thyroid medication

<u>Procedure</u>

Tasks and instructions

1. *Maximum Phonation time (MPT):* sustained productions of the three vowels /a/, /i/ and /u/ and /s/ and /z/ at comfortable pitch and loudness for maximum time in a single breath.

- The participants were asked to take a deep breath and phonate /a/ as long as possible at a comfortable loudness and pitch. It was also demonstrated before the participant began the task. Similar instructions were given for /i/ and /u/.
- The participants were instructed to phonate /s/ as long as they can in one breathe at comfortable pitch and loudness. Similarly, they were instructed to sustain /z/.

2. *Reading task:*

The participants were asked to read a standardized reading passage for 1 minute in English language.

All the tasks were recorded individually in a quiet environment using a digital recorder (Olympus Digital Voice Recorder WS-100) with the microphone positioned at the distance of 10 cms from the subject's mouth during the recording in a comfortably seated position.

<u>Instrumentation</u>

The Multi Dimensional Voice Program (MDVP) and Real Time Pitch (RTP) software of the Computerized Speech Lab (CSL) 4500 were used for analyses of the data. Phonation samples were subjected to MDVP analysis and 29 acoustic parameters were extracted. Monologue samples were analyzed using RTP and five acoustic measures were extracted. Praat version 6.0.29 (Boersma & Weenink, 2017) was used to note the Maximum Phonation time (MPT) of the vowels and fricatives for s/z ratio.

Analyses

1. Aerodynamic analysis

(i) *Maximum Phonation time (MPT):* The phonation duration of all the three trials of vowels /a/, /i/ and /u/ were measured using Praat software as the time difference from the onset to the offset of the phonation in seconds.

(ii) *S/Z Ratio:* The phonation of /s/ and /z/ was measured using Praat software as the time difference from the onset to the offset of the phonation. The longest duration of each consonant was noted down as the maximum duration. The maximum duration of /s/ divided by the maximum duration of /z/ gave the s/z ratio.

2. Acoustic analyses

It were measured using Multi-Dimensional Voice Program (MDVP) software of CSL 4500 model (KAY PENTAX, New Jersy, USA).

Parameters extracted in MDVP

I. Fundamental Frequency Information Measures

- Mean Fundamental Frequency (MF0): Average value of all extracted period to period fundamental frequency values.
- Highest Fundamental Frequency (Fhi): Highest fundamental frequency value in phonation.
- Lowest Fundamental Frequency (Flo): Lowest fundamental frequency values in phonation.

- Standard Deviation of Frequency (STD): Variation of F0 within the analyzed voice sample.

II. Short and Long Term Frequency Perturbation Measures

- Absolute Jitter (Jita): An evaluation of period-to-period variability of pitch period with in the analyzed voice sample.
- Jitter Percent (Jitt%): Relative evaluation of period-to-period (very short- term) variability of the pitch within analyzed voice sample.
- Relative Average Perturbation (RAP): Relative evaluation of period-to-period variability of the pitch within analyzed voice sample with a smoothing factor of 3 periods.
- Pitch Perturbation Quotient (PPQ): Relative evaluation of period-to-period variability of the pitch within analyzed voice sample with a smoothing factor of 5 periods.
- Smoothed Pitch Perturbation Quotient (sPPQ): Relative evaluation of the short or long term variability of the pitch period within the analyzed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods. Voice break areas are excluded.
- Fundamental Frequency Variation (vF0): Variation of the fundamental frequency.

III. Short and Long Term Amplitude Perturbation Measures

- Shimmer in dB (ShdB): It is the period to period variability of the peak to peak amplitude within the analyzed voice sample.
- Shimmer Percent (Shim%): It is the relative evaluation of the period-period variation of the peak to peak amplitude within the analyzed voice sample.

- Amplitude Perturbation Quotient (APQ): Relative evaluation of the period-period variation of the peak to peak amplitude within the analyzed voice sample at smoothing of 11 periods.
- Smoothed Amplitude Perturbation Quotient (sAPQ): It is a relative evaluation of the short or long term variability of the peak to peak amplitude within the analyzed voice sample at smoothing factor defined by the user. The factory setup for the smoothing factor is 55 periods (providing relatively long-term variability; the user can change this value as desired). Voice break areas are excluded.
- Peak Amplitude Variation (vAm): It is the relative standard deviation of the peak to peak amplitude.

IV. Voice Break Related Measures

- Degree of Voice Breaks (DVB): The ratio of total length of voice breaks to voicing.
- Number of Voice Breaks (NVB): Number of times the fundamental period interrupted during the voice sample.

V. Sub-Harmonic Related Measures

- Degree of Sub Harmonic Segments (DSH): Estimated relative evaluation of sub-harmonics to F0 components in the voice sample.
- Number of Sub Harmonic Segments (NSH): Number of auto correlation segments where the pitch was found to be a sub-harmonic F0.

VI. Voice Irregularity Related Measures

- Degree of Voice less (DUV): Estimated relative evaluation of non-harmonic areas (where F0 can't be detected) in the voice samples.

- Number of Unvoiced Segments (NUV): Number of unvoiced segments detected during the auto-correlation analysis.

VII. Noise Related Measures

- Noise to Harmonic Ratio (NHR): Average ratio of harmonic energy in range of 1500-4500 HZ to harmonic energy in the range of 70-4500 Hz.
- Voice Turbulence Index (VTI): A ratio of the spectral in-harmonic high frequency energy in range 1800-5800 Hz to the spectral harmonic energy in the range 70-4200 Hz.
- Soft Phonation Index (SPI): Average ratio of the lower frequency harmonic energy in the range of 70-1550 Hz to the higher frequency harmonic energy in the range of 1600-4200 Hz

Parameters extracted in RTP

The acoustic parameters of speaking were extracted by considering the middle 40 seconds segment for acoustic analysis from the monologue.

Pitch related parameters:

1. Mean F0 (SM F0): Mean F0 reports the harmonic mean. It is the arithmetic mean for all the voiced frequency values in the sample.
2. Minimum F0: One of the extremes of data distribution reflecting the lower limit, or the lowest value, among the captured data. The minimum F0 refers to the lowest pitch value recorded.

3. Maximum F0: One of the extremes of data distribution, in this case reflecting the upper limit, or the highest value, in the RTP data. The maximum F0 refers to the highest pitch value recorded.
4. Standard Deviation in F0: this is a measure of variability in the data. It reflects the spread of the data, or the average amount by which the data deviates from the harmonic mean.
5. Fundamental frequency variation (vF0): The vF0 is defined as standard deviation F0 divided by the arithmetic mean (Mean Frequency). It is useful in facilitating comparisons regardless of F0 obtained.

Statistics

SPSS version 17 was used for statistical analysis of the parameters Descriptive statistics was employed to find the mean, median and standard deviation of the extracted parameters. The Mann- Whitney U- test was administered to derive the significance of comparison in the groups with respect to phonation and reading analysis as well as the aerodynamic measures.

CHAPTER IV

Results and Discussion

The voice characteristics of the experimental and control group were analyzed using aerodynamic and acoustic analyses. Maximum Phonation Time (MPT), s/z ratio were measured. Sustained phonation and reading tasks were used to extract acoustic parameters with MDVP and RTP software. MDVP analysis of phonation revealed that the measures of Voice Breaks, Sub-Harmonic and Voice Irregularity related were zero owing to continuous, controlled phonation and hence were not considered for the statistical analysis. Remaining parameters, i.e., measures of Fundamental frequency measures, Short and long term frequency perturbation measures, Short and long term amplitude perturbation measures and Noise related measures were subjected to statistical analysis using SPSS version 20. Acoustic measures of speech using RTP software were also subjected to statistical analysis using SPSS version 20. Descriptive statistics was done and then the normality of the parameters was checked using the Shapiro Wilk's test. Mean, median and standard deviation (SD) were extracted. Many of the parameters were not normally distributed - as the data did not follow the normal distribution ($p>0.05$) and maximum data had the $p<0.05$, therefore non parametric Mann Whitney U Test was administered to compare the two groups and check for significance.

The results are presented in tables 1- and discussed under the following sub-headings:

A. Acoustic analysis for phonation

B. Acoustic analysis for reading passage

C. Aerodynamic analysis.

A. Acoustic analysis for phonation

Table 1 reveals the details of mean, median, SD and Z scores for phonation for the participants in the control and experimental groups. The mean and median values of all the measures of fundamental frequency information related and short-long term frequency perturbation measures were higher for subjects in control group than the experimental group.

Table 1: Mean, SD, Median, and Z score for the acoustic measures vowel phonation across the two groups

Parameter	Experimental group			Control group			Sig.
	Mean	SD	Median	Mean	SD	Median	Z
	Fundamental frequency related measures						
MF0	203.28	21.75	198.48	210.66	21.21	201.93	.14
Fhi	209.19	22.62	203.58	218.09	21.06	213.67	.07
Flo	197.50	21.14	193.90	203.90	20.72	195.51	.23
STDF0	2.08	.78	2.01	2.38	.69	2.30	.07
Short and Long term frequency perturbation measures							
Jitta	50.68	25.64	43.06	54.95	28.01	54.86	.57
Jitt	1.02	.53	.94	1.11	.56	1.14	.58
RAP	.62	.33	.57	.69	.35	.72	.48
PPQ	.58	.30	.52	.63	.34	.62	.64
sPPQ	.65	.22	.67	.74	.30	.72	.27
vF0	1.01	.34	1.04	1.13	.33	1.12	.17

Short and Long term amplitude perturbation measures							
ShdB	.31	.10	.30	.31	.10	.29	.92
Shim	3.61	1.32	3.47	3.67	1.20	3.37	.97
APQ	2.74	.90	2.53	2.75	1.02	2.34	.90
sAPQ	4.52	1.52	4.30	4.37	1.60	3.92	.49
vAm	7.82	2.88	8.09	7.64	3.03	7.00	.79
Noise related measures							
NHR	.18	.23	.14	.13	.02	.14	.53
VTI	.03	.01	.04	.03	.01	.04	.86
SPI	16.68	11.79	11.57	14.05	4.70	13.78	.79

*Significance level $p<0.05$

It was noted from Table 1 that the mean values for ShdB (0.31) and VTI (0.03) and the median for VTI (0.04) were same for participants in both the groups. Further, only the mean values were higher for Shim and APQ in control group participants whereas it was increased for all other measures, namely, sAPQ, vAm, NHR and SPI in the participants of the experimental group. The medians showed mixed results across the participants of the two groups. But Mann Whitney U test did not show significance across the two groups (as $p> 0.05$) for any of these parameters.

All the subjects revealed fundamental frequency that was appropriate to the age and gender and is in consonance with the results of Aronson and Bless (2009) who had put forth that the mean fundamental frequency of the females is 212Hz and the range 197- 227 Hz.

However, participants in the experimental group had slightly lower mean MF0, FHi, Flo, STDF0, Jitta, Jit%, RAP, PPQ, sPPQ, and vF0 compared to participants of the control group. According to Manuscript et al. (2007), the desiccated environment was hypothesized to alter the vocal fold surface dehydration and as a result, a change in viscosity was expected. This alteration in the viscosity was then expected to affect the fundamental frequency measures. However, as the differences between the participants of the two groups were lesser and significance was absent, it may be speculated that the air conditioned environment might not have altered the biomechanical properties of the vocal fold structure.

As we can note from the table 1, the difference in the F0 related and short and long term frequency perturbation measures across the two groups is minimum. Individual variations across subjects, personal and environmental factors could be the probable explanation for the minimum differences in mean and median values.

Hemler et al., (1997) reported a significant increase in the absolute and relative jitter and PPQ after immediate analysis of exposure to 10 minutes dry air conditions. Further, it was stated that the jitter and related measures decreased as soon as exposed to the humidified or standardized room environment. However these results are contradictory to the findings of the present study as participants in experimental group had lesser mean values for frequency perturbations indicating better frequency perturbations when compared to participants in the control group. It may also be noted that the F0 range was small in subjects of the experimental group as the difference between Fhi and Flo was 10Hz indicating more controlled phonation. Hence, frequency perturbations could have lesser mean values in the participants of the experimental group compared to the control group.

Amplitude perturbations are the period to period variability of the peak to peak amplitude. But most of the amplitude perturbations and noise related measures (sAPQ, vAm, NHR and SPI) were slightly increased in experimental group participants compared to the control group participants. Incomplete glottal closure, air leak could be speculated as the probable cause for these results. Further, the energy provided by the lungs air is not adequately converted into the sound energy and thus, a loss of energy resulting in breathiness would be expected. As the noise emissions and this breathiness correlates with the amplitude perturbations measures as they are dependent on the change in glottal resistance variation and even with the presence of the mass lesions in the vocal folds (Teixeira et al, 2013).

B. Acoustic analysis for reading

Table 2 reveals the details of mean, median, SD and Z scores for reading across the two groups of participants. It is depicted that the variation in the fundamental frequency measures in the reading task. It can be seen that the mean and median values are higher for control group for all the measures and the range of fundamental frequency is more in controls (87.25-381.03) than in experimental (97.59-368.78). There was a consistency in the trend seen for all the measures i.e., higher mean in the controls than in the experimental group participants (Table 2).

Table 2: Mean, Median, Standard Deviation (SD), Z score for the acoustic measures of the reading across the two groups.

Groups							
	Experimental			**Controls**			**Sig.**
	Mean	**SD**	**Median**	**Mean**	**SD**	**Median**	**Z**
MF0	215.74	23.39	209.95	221.94	18.18	220.33	.14
MinF0	97.59	26.04	91.03	87.25	16.33	84.99	.18
MaxF0	368.78	65.36	380.41	381.03	13.17	383.74	.67
STDF0	29.56	6.55	28.75	34.64	8.79	33.73	.00*
vF0	.13	.02	.13	.15	.03	.15	.01*

*Significance level $p < 0.05$

On the Mann Whitney U test, the significance was noted for the parameters STDF0 and vF0 across the participants of the two groups. Higher MF0, STDF0 in subjects of control group could be because of wide frequency range. The MF0 usually is increased if the difference between the MinF0 and MaxF0 is greater. Larger F0 range is expected in reading and indicates expressive speech and suggesting that the control group participants read more expressively than participants of the experimental group.

When the two tasks were compared, the participants in control group had higher mean MF0 and STDF0 as against the participants in experimental group. This shows a similar trend across the two tasks for control group participants. Phonation requires controlled sustained production of the designated vowel thereby, the difference between FHi and Flow being lesser. So it can be put forth that the participants could perform better controlled sustained production of the designated vowel /a/ compared to the experimental group. It may be speculated that the participants in the control group could have produced the two tasks at a higher loudness level compared to the participants of the experimental group because of the natural environment (non air conditioned). This finds support from Baken et al. (2010) who have postulated that the vocal F0 varies as a function of subglottal pressure, which in turn, is a major physiologic determinant of vocal intensity. Intense speech would have a higher F0 values.

C. Aerodynamic measures

The details of the descriptive statistics and results of significance for aerodynamic measures are shown in Table 3. The mean MPT was higher for vowels /a/ and /i/ but lower for /u/ in the participants of the experimental group when compared to the control group. However, it was noticed that the mean MPT values were lower in both groups of participants. The median values showed mixed trend across the vowels. The s/z ratio was within the normal range (Baken et al., 2010).

Table 3: Mean, Median, SD and Z scores for Aerodynamic measures

Groups							
	Experimental			Controls			Sig.
MPT	**Mean**	**SD**	**Median**	**Mean**	**SD**	**Median**	**Z**
/a/	12.21	2.56	11.90	11.90	3.88	11.45	.46
/i/	12.05	3.10	11.90	11.76	2.58	11.95	.87
/u/	11.80	3.16	11.15	13.69	2.97	12.90	.01*
s/z	1.05	.37	1.01	1.01	.38	.94	.57

*Significance level considered $p < 0.05$

The mean values and median values were consistently lower in controls for the MPT of /a/ and /i/, whereas the MPT of /u/ had higher values in controls. The difference between the same was statistically significant in MPT of /u/ ($p < 0.05$).

The mean value s/z ratio was higher in experimental group (1.05) than that of the control group (1.01). The median values also followed a similar trend. The higher s/z ratio is indicative of lowered /z/ duration which is a laryngeal supported sound and gives impression about the laryngeal system.

Overall, the aerodynamic measures revealed lower values in general when compared to reported results in literature. The probable reason for the lowered mean MPT values for all the vowels and fricatives could be the unfamiliarity of the tasks. The findings of Neiman & Edeson, 1981; Soman, (1997) emphasizes the importance of practice and attention playing major roles in eliciting expected results on aerodynamic parameters could be another probable cause for the findings of the present study.

The acoustic measures of sustained phonation and a reading task were insufficient to delineate the differences across the participants in the experimental and control groups. Also the physiological variations if any has occurred may be difficult to detect due to multiple factors and their combination effects that may impact vocal mechanism. It is still premature to put forth the minimum amount of time of exposure to air conditioner environment that could result in significant changes in the vocal mechanism. But as the singers have shown effects of air conditioned environment on their voice and studies have put forth that the high pitch sustained vowel shows deviancy in the parameters measured; a change in task could help determining the effects in the future. Even the combination of the dehumidified environment along with another variable like drugs, or personality trends, could be done to see the effects of the same. Most of the earlier literature has focused on the singers and the immediate effects of the exposure to the air conditioned environment and the results revealed that the acoustic parameters important for the singers were affected in the dehumidified environment.

CHAPTER V

Summary and Conclusion

The present study aimed to explore the voice quality of the individuals exposed to the air conditioned environment for a prolonged period of time. A total of 60 participants were considered, which were divided into the two groups of 30 individuals exposed to centralized air conditioned environment who formed the experimental group and 30 individuals who were not exposed to air conditioned environment formed the control group.

Acoustic analysis was carried out for the sustained phonation of vowel /a/ and reading using MDVP and RTP respectively of CSL 4500 and MPT of /a/,/i/, /u/ and s/z ratio also recorded. After MDVP analysis of phonation measures of Fundamental frequency measures, Short and long term frequency perturbation measures, Short and long term amplitude perturbation measures and Noise related measures and the F0 measures of reading using RTP software were subjected to statistical analysis using SPSS version 20. Measures of Voice Breaks, Sub-Harmonic and Voice Irregularity related were zero owing to continuous, controlled phonation and hence were not considered for the statistical analysis. The results could be summarized as; in phonation the mean and median values of all the measures of fundamental frequency information related and short-long term frequency perturbation measures were higher for subjects in control group than the experimental group. Acoustic analysis of reading revealed that the mean and median values are higher for control group for the all the measures and the range of fundamental frequency is more in controls

(87.25-381.03) than in experimental (97.59-368.78). There was a consistency in the trend seen for all the measures i.e., higher mean in the controls than in the experimental group participants. Of the aerodynamic measures, the mean MPT was higher for vowels /a/ and /i/ but lower for /u/ in the participants of the experimental group when compared to the control group. However, it was noticed that the mean MPT values were lower in both groups of participants. The median values showed mixed trend across the vowels. The s/z ratio was within the normal range.

But these results did not indicate significant difference across the two groups. Hence, the results of the present study could be taken as a preliminary attempt to check the effects of prolonged air conditioner as the possible causative variable while it cannot be generalized due to the small sample size and attributing confounding variables. The age range of the participants was wide and could be another confounding variable.

Through this study, an attempt was made to observe whether that the present day trend of converting the work environment as a compulsory air conditioned environment is a boon or a curse. Though the results did not reveal significant differences across the participants with and without air conditioned environment exposure, it sure will warrant the inclusion of this criterion as a prerequisite in the assessment protocol for professional voice users.

Future attempts could include analysis of vocal mechanism using invasive procedures to note the morpho-physiological changes of vocal folds, if any, as an early indicator of later voice variations and also voice profiling controlling the type of air conditioned environment (centralized) where the temperature is constant as in laboratories, ductless air conditioners and home air conditioners duct air conditioners.

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