VOICE CHARACTERISTICS AND RECOVERY PATTERNS IN INDIAN ADULT MALES AFTER VOCAL LOADING

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Abstract

The study aimed to measure the effects of vocal loading on voice characteristics in Indian adult males, to document complaints associated with vocal fatigue and to monitor recovery patterns of voice after the vocal loading task. Twenty adult males between the ages of 18 and 30 years participated in this study. The subjects were instructed to read a book at 75-80 dB SPL up to an hour or until they reported themselves as fatigued. Pre and post experiment voice assessments were carried out using GRBAS scale and MDVP analysis. The duration of prolonged reading and signs of vocal fatigue were documented. Voice recovery was tracked at 5, 10, 15, 20 minutes and 24 hours following the immediate post experiment. Paired t test and repeated measure of analysis of variance (ANOVA) were used for statistical analysis. Overall quality of voice change (Grade) was more pronounced after vocal loading. Significant reduction (around 6 seconds) in maximum phonation time and a significant increase in S/Z ratio were found. MDVP analysis revealed significant decrease in lowest fundamental frequency and increase in phonatory fundamental frequency range, short and long term frequency and amplitude measurements, noise and voice irregularity related measures after vocal loading. Initial signs of fatigue such as throat pain, throat tightness and running out of breath were noticed as early as 15 minutes and subjects were able to sustain the task for not more than 30 minutes. Short and long term frequency and amplitude measures and noise to harmonics ratio revealed a significant recovery pattern. Complaints of vocal fatigue, voice symptoms, and vocal recovery after vocal loading can be tracked and monitored using perceptual and acoustic measures. These findings can be applied to understand vocal endurance, susceptibility to vocal fatigue and physiological changes due to vocal loading.

Key words: vocal loading task, GRBAS, MDVP, vocal endurance and susceptibility

Terms ‘vocal abuse’ and ‘vocal misuse’ occur frequently in discussion of voice disorders related to vocal hyperfunction. Phonation under these conditions results in tissue changes in larynx which alters the mass, elasticity and tension of the vocal folds. The tissue changes and mechanical alterations of the vocal folds together result in abnormal production of voice and vocal fatigue.

Many individuals report symptoms of vocal fatigue after extended voice use. Vocal fatigue is a frequent complaint among individuals who depend on their voice for their profession and those who have disordered voice. The mechanical basis of vocal fatigue is not well known. Titze, 1983 (as cited in Callaghan, 2000) postulated that vocal fatigue is linked to inefficient use of mechanism and dehydration. Vocal fatigue may result from both the fatiguing of the respiratory and laryngeal muscles and from bio-mechanical challenges in non muscular tissues that cause the vocal folds to vibrate less efficiently. Symptoms of vocal fatigue include complaints of increased effort to talk, not able to talk continuously and a tired, weak voice (Smith, Kirchner, Taylor, Hoffman & Lemke, 1998). One common scenario of excessive voice use is a condition in classrooms which involves teaching for long hours, which is usually referred to as vocal loading. Kelchner, Toner and Lee (2006) defined vocal loading

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as "Prolonged loud voice use and has four distinct phases: warm up (adapting to the voicing task), performance (continuance of the voicing task), vocal fatigue (perceived increase of physical effort associated with voicing; physical challenges to the larynx), and rest or recovery". Prolonged loud reading is one of the vocal loading task that is most often used to mimic excessive usage of voice (Stemple, Stanley & Lee, 1995; Kelchner, Lee & Stemple, 2003; Kelchner et al., 2006). These prolonged loud reading protocols vary with reference to procedural variations, loudness levels and total time spent on reading. Most reported outcome data involving vocal loading task include comparisons of pre and post perceptual, acoustic, stroboscopic and aerodynamic measures (Stemple, et al., 1995; Kelchner et al., 2003; Kelchner et al., 2006).

Voice use can also be documented by using voice accumulators (Ohlsson, Brink & Löfqvist, 1989) and portable DAT recorders (Södersten, Granqvist, Hammarberg & Szabo, 2002; Rajasudhakar & Savithri, 2009). Other methods include vocal loading measurements in experimental conditions (Stemple et al., 1995; Kelchner et al., 2003; Kelchner et al., 2006) and work environments or real life situations (Rajasudhakar & Savithri, 2009). The experimental methods used a procedure which was similar to classroom and other vocal loading conditions (singing, acting) thereby measuring the effects of it on voice production. Several methods have been developed over the years to document the amount of voice use in professional voice users especially teachers during work and other experimental conditions. Krishna and Nataraja (1995) developed criteria for susceptibility to vocal fatigue in 5 teachers and 5 non-teachers based on MDVP parameters before and after an hour of loud reading. Teachers as a group showed significant changes in the acoustic parameters like average fundamental frequency (F_o), average pitch period (t_o), standard deviation of F_o (STD), highest fundamental frequency (F_{hi}) and lowest fundamental frequency (F_{lo}) after reading. However, this study was limited to describing acoustic changes after vocal loading without mentioning recovery patterns across time and effects of observing vocal hygiene and conservative voice use post vocal loading task. Other studies have examined various factors related to vocal loading such as environment (Södersten et al., 2002), health (Roy, Merrill, Thibeault, Parsa, Gray & Smith, 2004) and stress related (Smith et al., 1998).

There are numerous social and educational situations an adult may engage in using loud voice. These events can often result in voice change and complaints of vocal strain and fatigue. People who use their voice excessively are at risk for voice disorders. Boominathan, Rajendran, Nagarajan, Muthukumaran and Jayashree (2008) studied regarding vocal abuse and vocal hygiene practices among different levels of professional voice users (teachers, singers, vendors & politicians) in India. The results indicated alarming levels of vocally abusive behaviors and poor vocal hygiene practices among the groups studied.

These increased occurrences of vocally abusive behaviors in professional voice users could possibly be applied to general population as well. Vocally abusive behaviors lead to vocal hyperfunction and is generally believed that vocal hyperfunction is an underlying component in majority of voice disorders (Boone, 1983, as cited in Hillman, Holmberg, Perkell, Walsh & Vaughan, 1989).

Apart from information regarding vocal abuse and hygiene practices, understanding the vocal health status of normal adults becomes important. Data on vocal health may facilitate prevention and management of voice problems in adults. Further, understanding of the effects of vocal loading, fatigue and endurance may be the first step to define vocal health physiologically. In this connection, the present study aims to add information on the effects of controlled prolonged loud voice use and resulting complaint of vocal fatigue or voice change and recovery pattern of voice in the healthy adult Indian males.

Method

Subjects

Twenty normal adult Indian males between the ages of 18 and 30 years participated in this study. The subjects were recruited based on the exclusion and inclusion criteria given below.

Exclusion criteria:

1. History of smoking, laryngeal pathology, intubation, neurologic disorder, respiratory disorder, systemic illness, and surgery/ accident/

trauma,

2. Sustained (prolonged use) medications for any medical condition,
3. Underweight or obesity (National Institute of Health, 2000, as cited in Taylor, Lillis & Lemone, 2007).

Inclusion criteria:

1. Perceptually normal voice in terms of pitch, loudness and quality,
2. Loudness dynamic range of 40 - 80 dBSPL.

Procedure

I. Pre-experiment phase

***Directions to subjects prior to participation in the experiment*:** Every subject was asked to refrain from excessive voice use (yelling, prolonged singing / talking, whispering and throat clearing), to avoid caffeine, and was instructed to drink adequate water (6-8 glasses) for 24 hours preceding their appointment to participate in the experiment.

Pre experimental recording for obtaining baseline measures: To obtain baseline measures, the subjects were asked to phonate /a/, /i/, /u/ and sustain /s/, /z/ as long as possible and speak (1minute) at their comfortable pitch and loudness before performing the experimental task. The subjects were seated in a comfortable upright posture and the recording was done with a microphone (SM 48) distance of 10 cm from the mouth, at an off angle position of 45°. The signal was recorded using KAY Computer Speech Lab model 4300 (Kay Elemetrics Corp., NJ, USA), at 44,100 Hz sampling rate.

Pre experiment analysis for baseline measures:

a) Perceptual analysis: Phonation and conversation samples were judged for the perceptual correlates of voice by a qualified Speech Language Pathologist for parameters of pitch, loudness and quality. The judge performed the perceptual evaluation in one session with two pauses, and there was no limit as to how many times the judge was allowed to listen to each of the voice samples. For intra-judge reliability the samples were reanalyzed entirely with a minimum gap of 1 day. Maximum Phonation Time (MPT) and S/Z ratio were also analyzed and noted. The GRBAS scale (Hirano, 1981) was used for the perceptual analysis of voice in conversation tasks.

b) Acoustic analysis (PrT): The recorded phonation sample was analyzed using Multi Dimensional Voice Profile (model 5105, Kay Elemetrics Corp., NJ, USA). The first portion of the phonated sample /a/ (0.25 s) was cut off, and measurements were performed during the subsequent 3.0 seconds, thus minimizing variability caused by sampling errors. The remaining portions of the sample were discarded, which ensured that the initial and final parts of voicing did not influence the final result. The recorded phonation samples were analyzed for frequency related (F_o), amplitude related (I_o), voice break, noise related, sub-harmonic component, voice irregularity and voice tremor related measures.

II. Experimental phase

***Prolonged loud reading task*:** A calibrated (acoustic calibrator 4231) Sound Level Meter (SLM) (Bruel & Kjaer sound analyzer 2260) with a pre-polarized free field ½ inch condenser microphone (Model 4189) was mounted on a stand and kept at a distance of 18 inch from the subject's mouth. Using the SLM as a guide for intensity, the subjects were instructed to read a book or reading material of their interest at 75-80 dB SPL in standing posture upto an hour or until they reported themselves as fatigued.

The experimenter cued the subject to maintain comfortable pitch and loud intensity level as needed, and monitored I_o for every 30 seconds for the entire duration of prolonged loud reading task. The experimenter monitored and noted the time of initial sign of vocal fatigue from the beginning of the reading. The number of times the experimenter asked the subject to increase his loudness after the initial sign of vocal fatigue was also recorded. The frequency of reminder was taken as a subjective indicator of vocal fatigue.

In case, a subject was unable to read at that intensity level for 1 hour, the reading was terminated and the duration of prolonged reading was noted. In addition, the experimenter observed for any physical or vocal signs of discomfort (e.g. coughing, throat clearing, & voice quality change). These signs were meticulously noted by the experimenter.

III. Post experiment phase

Directions to subjects after the participation in the experiment: Subjects were asked to remain silent between the termination of the prolonged loud reading task and the immediate post-test assessment. The subjects were asked to follow strict vocal hygiene guidelines: 1) no extreme voice use (yelling, prolonged singing, talking, whispering & throat clearing), 2) avoid caffeine, 3) avoid smoking, 4) coughing, 5) throat clearing, and 6) drink adequate amounts of water for 24 hours after the experimental task. The subjects were refrained from throat clearing until the post evaluation procedures were completed.

Post experiment recording and analysis: Following the prolonged loud reading task, the phonation and conversation samples were recorded again as mentioned in baseline measurements and MDVP parameters were analyzed. MPT and S/Z ratio were also analyzed. The data obtained immediately after vocal loading task served as immediate post-test measurements, which was named as P_oT_o.

Voice recovery was tracked at 5, 10, 15 and 20 minutes and 24 hours following the immediate post test, which were named as P_oT_5, P_oT_{10}, P_oT_{15}, P_oT_{20}, and P_oT_{24hr} respectively.

Paired *t* test was used to measure the pre and post test voice measures. A repeated measure of analysis of variance (ANOVA) was performed on P_oT_o, P_oT_5, P_oT_{10}, P_oT_{15}, P_oT_{20}, and P_oT_{24hr} to measure the recovery of vocal function.

Results & Discussions

I. Pre and immediate post-experiment comparisons

Perceptual analysis of phonation and conversation: The pre-experiment (PrT) analysis for phonation and conversation sample was judged to be normal with respect to pitch, loudness and quality. Immediate post vocal loading task (P_oT_o) analysis of phonation samples revealed pitch deviancies (low pitched phonation), loudness deviancies (soft phonation) and quality deviancies (hoarse & breathy voice) in phonation. The results are tabulated in Table 1. This change was observed in 100% of the subjects on the immediate post vocal loading task. Acoustic analysis (discussed later) ascertains the perceptual findings. These changes are attributed as effects of vocal loading. However, contrary to these findings, Kelchner et al. (2003) assessed quality in phonation after the vocal loading task and reported no significant difference in the voice quality.

Scale	Severity	PrT	P_oT_o
Grade	Normal	100 %	50 %
	Mild	0 %	50 %
	Moderate	0 %	0 %
	Severe	0 %	0 %
Roughness	Normal	100 %	50 %
	Mild	0 %	50 %
	Moderate	0 %	0 %
	Severe	0 %	0 %
Breathiness	Normal	100 %	87.5 %
	Mild	0 %	12.5 %
	Moderate	0 %	0 %
	Severe	0 %	0 %
Asthenia	Normal	100 %	92.5 %
	Mild	0 %	7.5 %
	Moderate	0 %	0 %
	Severe	0 %	0 %
Strain	Normal	100 %	100 %
	Mild	0 %	0 %
	Moderate	0 %	0 %
	Severe	0 %	0 %

Table 1: Perceptual evaluation of conversation samples using GRBAS scale obtained from Pre (PrT) and immediate post experiment (P_oT_o) recordings.

The pre-experiment analysis for conversation samples was judged to be normal with respect to grade, roughness, breathiness, asthenia and strain. The post experiment revealed 0 % strain. This may be due to the difficulty in identifying strain. Both grade and roughness showed 50 % mild deviancies. Breathiness (12.5 %) and asthenia (7.5 %) were less commonly observed in the conversation samples.

To check intra-judge reliability for phonation and conversation samples, Spearman coefficient of correlation was done. Statistically significant correlation was obtained between the repeated ratings made by the judge at two different times (phonation- +0.37; conversation- +0.25). Hence the perceptual evaluation by the judge was considered reliable.

a) MPT and S/Z ratio: The maximum phonation time (MPT) for /a/, /i/, /u/ and S/Z ratio was measured pre and post experiment (PrT & P_oT_o) to obtain status of laryngeal function and coordination with breathing mechanism after the vocal loading task. The results are given below in Table 2.

Parameters (unit)		PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
MPT (sec)	/a/	19.39 (2.59)	14.00 (3.15)	0.000	+
	/i/	19.17 (2.52)	13.42 (3.19)	0.000	+
	/u/	19.27 (2.64)	13.47 (3.42)	0.000	+
S / Z Ratio		1.00 (0.03)	1.23 (0.08)	0.000	+

Table 2: Mean, standard deviation and p - values for maximum phonation time and S/Z ratio.

Table 2 revealed a significant reduction in MPT after the vocal loading task. The reduction in MPT ranged from 4 – 8 seconds. On contrary, Kelchner et al. (2006) found no significant difference in MPT in pre-pubescent males after the vocal loading task. The S/Z ratio also revealed a significant increase in post-test. Higher S/Z ratio indicates poor laryngeal control rather than poor expiratory forces. Eckel and Boone, 1981 (as cited in Prater & Swift, 1984) found that 95 % of their patients with laryngeal pathologies had S/Z ratios that were greater than 1.40. For better identification of laryngeal pathologies, it has been recommended that S/Z ratio greater than or equal to 1.20 to be used as the cutoff value. The significant differences in MPT and S/Z ratio could be taken as an effect of vocal loading on the coordination of respiratory and the laryngeal mechanism.

a) Acoustic analysis: Mean, standard deviation and *p* values for the acoustic measures are tabulated based on the different parameters specified in MDVP. A series of two tailed paired *t* tests for correlated samples was run for each of the acoustic measures to determine statistical difference between the pre (PrT) and post experiment (P_oT_o) data.

i) Frequency related parameters: Mean, standard deviation and *p* - values for the frequency related parameters are tabulated in Table 3.

Table 3 indicated no significant differences for most of the frequency related measures, except for phonatory fundamental frequency range (PFR) and lowest fundamental frequency (F_{lo}). The PFR showed an increase in values and F_{lo} revealed a decrease in the values. The slight decrease in F_o, F_{lo} and increase in PFR was in strong agreement with the perceptual findings reported in this study. Similarly, Neils and

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
F_0 (Hz)	145.1 (25.2) 25.2	140.8 (20.6) 20.6	0.305	-
F_{hi} (Hz)	153.8 (26.3) 26.3	164.1 (31.7) 31.7	0.196	-
F_{lo} (Hz)	137.9 (22.9) 22.9	127.4 (22.3) 22.3	0.023	+
STD (Hz)	2.4 (2.5) 2.5	3.4 (1.7) 1.7	0.128	-
PFR (Semitones)	2.9 (0.91) 0.91	5.3 (3.3) 3.3	0.005	+

Table 3: Mean, standard deviation and *p* values for frequency related measures.

Yairi, 1987 (as cited in Rantala & Vilkman, 1999) reported no significant changes in F_o in vocally untrained women following 45 minutes of reading in background noise (50 – 70 dB A).

However, Krishna and Nataraja (1995) found significant differences in average fundamental frequency (F_o), average pitch period (t_o), standard deviation of F_o (STD), highest fundamental frequency (F_{hi}) and lowest fundamental frequency (F_{lo}) after a 30 minutes reading task. In a similar study, Stemple et al. (1995), Gefler and Andrews, 1991 (as cited in Stemple et al., 1995) and Vilkman, Lauri, Alku, Sala and Sihvo (1999) documented increase in habitual F_o following prolonged voice use. This discrepancy may be due to variations in duration of vocal loading tasks and gender differences across the studies.

ii) Short and long term frequency measurements: Table 4 showed mean and standard deviation of frequency perturbation measures. Measures such as jitter in % (Jitt), relative average perturbation (RAP), pitch period perturbation quotient (PPQ), smoothed pitch perturbation quotient (sPPQ) and absolute jitter (Jita) showed significant difference and vFo did not show any significant difference in pre and immediate post experiment. All these parameters measure the short and long term variations of the pitch period within the analyzed sample. The increase in the short and long term frequency measurements may be due to irregular vibration of the vocal folds. This altered mode of vibration could have lead to an increase in frequency perturbation measures. These changes are attributed as effects of vocal loading.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	P	Significance
Jitt (%)	0.50 (0.20) 0.20	1.62 (0.97) 0.97	0.000	+
RAP (%)	0.29 (0.13) 0.13	0.97 (0.59) 0.59	0.000	+
PPQ (%)	0.29 (0.12) 0.12	0.92 (0.54) 0.54	0.000	+
sPPQ (%)	0.56 (0.12) 0.12	1.14 (0.51) 0.51	0.000	+
vFo (%)	1.63 (1.53) 1.53	2.33 (1.30) 1.30	0.118	-
Jita (usec)	35.5 (12.8) 12.8	116.8 (70.1) 70.1	0.000	+

Table 4: Mean, standard deviation and *p* - values for short and long term frequency related easures.

The finding in the present study also stands in support of the results from Gelfer et al.,1991 (as cited in Stemple et al., 1995) that found a significant change between pre- and post test Jitter ratio for the vowel /i/ in trained singers after vocal loading task. In contrast to this findings, Verstaete, Forrez, Mertens and Debruyne, 1993 (as cited in Welham & Maclagan, 2004) found no significant changes in jitter values in untrained voice users.

iii) Short and long term amplitude measurements: The amplitude perturbation measures in Table 5 indicated a significant increase in all the measures such as shimmer (Sh dB), shimmer percent (shim), amplitude perturbation quotient (APQ), smoothed amplitude perturbation quotient (sAPQ), and peak amplitude variation (vAm).

All these parameters measure the period-to-period variability of peak to peak amplitude within analyzed sample. The higher values in amplitude measures can be explained as the inability of the subjects to maintain a constant intensity in phonation after the vocal loading task. However, Verstaete et al., 1993 (as cited in Welham & Maclagan, 2004) found no significant differences in shimmer values in untrained voice users.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
Sh dB (dB)	0.21 (0.05)	0.38 (0.20)	0.000	+
Shim (%)	2.31 (0.82)	4.37 (2.39)	0.000	+
APQ (%)	1.82 (0.45)	3.13 (1.58)	0.000	+
sAPQ (%)	3.41 (0.71)	4.99 (1.71)	0.000	+
vAm (%)	13.9 (4.93)	19.0 (5.49)	0.003	+

Table 5: Mean, standard deviation and *p* - values for short and long term amplitude related measures.

iv) Noise related parameters: The mean, standard deviation and significance of noise related measures such as soft phonation index (SPI), voice turbulence index (VTI) and noise to harmonics ratio (NHR) is showed in Table 6. The results showed a significant increase in NHR and SPI. Higher NHR values indicated that there is considerable increase in noise component in voice after vocal loading task and this may be due to increase in glottal gap during phonation. The other noise related VTI did not show a significant difference. On the contrary to these findings, Krishna and Nataraja (1995) found no significant difference in noise related measures.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
SPI	15.2 (10.5)	19.2 (8.9)	0.034	+
VTI	0.03 (0.01)	0.03 (0.01)	0.963	-
NHR	0.13 (0.01)	0.15 (0.01)	0.651	+

Table 6: Mean, standard deviation and *p* - values for noise related measures.

v) Voice break related parameters: Table 7 showed no significant variations in the pre- and post experiment values for voice break related measures such as degree voice breaks (DVB) and number of voice breaks (NVB). Therefore, indicating no effect of vocal loading task on voice break related measures. Krishna and Nataraja (1995) also found no significant differences in voice break measures.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
DVB (%)	0.00 (0.00)	0.18 (0.59)	0.186	-
NVB	0.00 (0.00)	0.10 (0.30)	0.163	-

Table 7: Mean, standard deviation and *P*- values for voice break related measures.

vi) Sub-harmonic component measures*:* The results in Table 8 show no significant variations in the pre- and post test values such as degree of sub harmonic segments (DSH) and number of sub harmonic segments (NSH). Therefore, indicating vocal loading task is not affecting sub-harmonic components in the current study. Krishna and Nataraja (1995) also found no significant differences in sub-harmonic component measures.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
DSH (%)	0.03 (0.09)	0.35 (0.93)	0.132	-
NSH	0.10 (0.30)	1.1 (2.8)	0.116	-

Table 8: Mean, standard deviation and *p* - values for sub-harmonic component related measures

vii) Voice irregularity related measurements: The results in Table 9 showed significant variations in the pre- and post test values for voice irregularity parameters such as degree of unvoiced segments (DUV) and number of unvoiced segments (NUV). This irregularity in voicing was due to the effect of vocal loading on vocal mechanism. However, Krishna and Nataraja (1995) found no significant differences in voice irregularity measures.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significan
DUV (%)	0.08	1.2	0.06	+
NUV	0.25 (0.63)	2.9 (5.8)	0.05 7	+

Table 9: Mean, standard deviation and p - values for voice irregularity related measures.

viii) Voice tremor related measurements: The mean, standard deviation and significance of voice tremor related measures such as Fo- tremor frequency (Fftr), amplitude tremor frequency (Fatr), frequency tremor intensity index (FTRI) and amplitude tremor intensity index (ATRI). Table 10 showed significant increase for FTRI and Fftr measures. This may be explained due to the tremor component in the voices of the subjects after the vocal loading task. There were no significant differences noticed for the other voice tremor related measures.

Parameters (unit)	PrT Mean (SD)	P_oT_o Mean (SD)	p	Significance
Fftr	1.8 (1.9)	4.1 (3.3)	0.024	+
Fatr	1.6 (1.8)	2.1 (2.1)	0.446	-
FTRI	0.1 (0.1)	0.4 (0.3)	0.005	+
ATRI	1.3 (1.4)	2.6 (2.9)	0.107	-

Table 10: Mean, standard deviation and p- values for voice tremor related measures.

ix) Prolonged reading task - duration as an indicator of vocal fatigue: The overall mean and standard deviation for duration of total loud reading time and notice of initial fatigue are described in Table 11.

Parameters	Minimum	Maximum	Mean (SD)
Total reading time (minutes)	30	45	35 (4.34)
Initial fatigue noticed (minutes)	10	23	15 (3.36)
Frequency of reminder (number)	13	21	16 (2.28)

Table 11: Minimum, Maximum, Mean and standard deviation for duration of prolonged reading and symptoms of initial fatigue.

In the current study, the length of time an individual could maintain loud reading task was subjectively interpreted as a partial indicator of vocal fatigue or endurance. Krishna and Nataraja (1995) suggested 30 minutes of reading was sufficient to induce fatigue. In the present study duration of reading ranged from 30 - 45 minutes. The mean duration of prolonged reading for subjects was 35 minutes with a standard deviation of 4.34. It was found that prolonged loud reading for 35 minutes itself was sufficient to induce vocal fatigue which was indicated by changes in the acoustic measures.

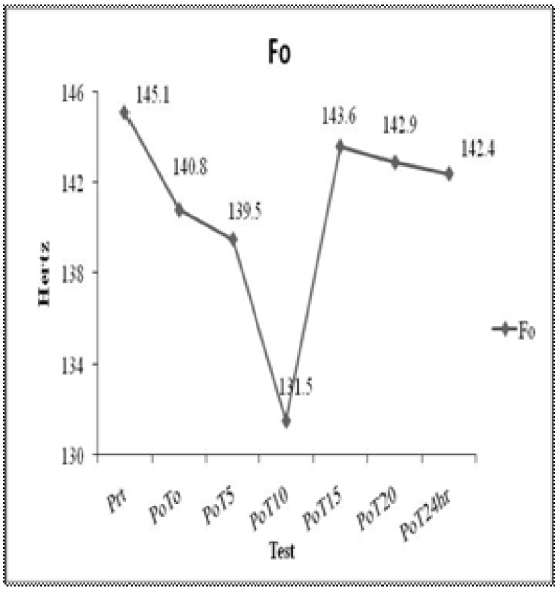
None of these subjects were able to complete the prolonged loud reading task for an hour. The time of initial fatigue revealed that all of the subjects reported fatigue before 25 minutes of the loud reading task. The mean duration of initial fatigue reported by the subjects was 15 minutes with a standard deviation of 3.36.

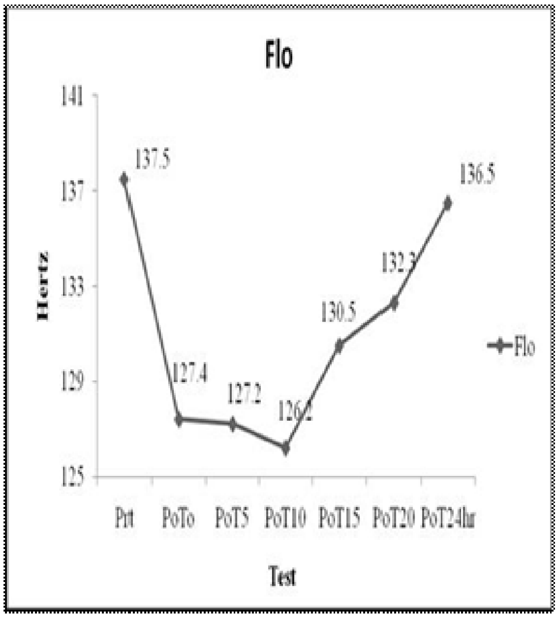
Majority of the subjects reported throat pain as a primary complaint along with throat tightness and running out of breath during prolonged loud reading task. These complaints correlate with some of the primary symptoms of vocal fatigue listed by Kostyk and Roche, 1998 (as cited in Welham & Maclagan, 2003).

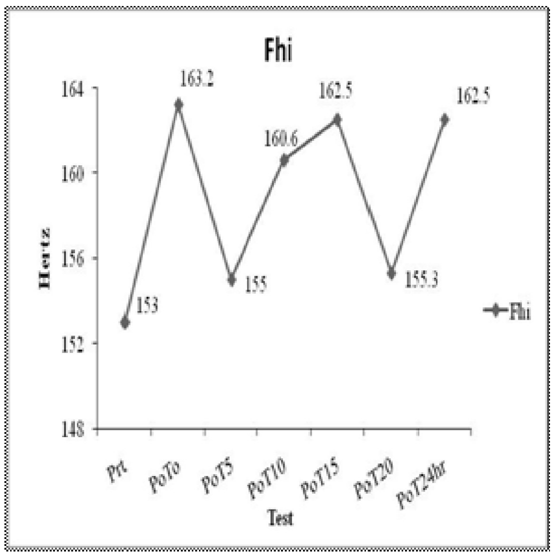
II. Immediate post comparisons with PoT5, PoT10, PoT15, PoT20, and PoT24hr Voice recovery pattern: The MDVP parameters were recorded before, immediately after and at each additional 5 minutes increment till 20 minutes and 24 hours following the experimental task. The subjects were asked to follow strict vocal hygiene guidelines for 24 hours after the experimental task. Repeated measures of ANOVA was used in which time was modeled as a within subject effect. Test results demonstrated a significant difference in the group for immediate post-test and post-tests till 20 minutes for some of the voice measures. Graphical representation of the recovery patterns of different voice measures are given below.

Frequency related measurements:

The frequency related measurements such as Fo, Flo, Fhi, STD and PFR did not show a significant recovery pattern through comparisons from the pretest to the post-tests till 20 minutes. However, Kelchner et al. (2006) documented significant recovery pattern for Fo in prepubescent males. This variation may be due to the duration and intensity of reading employed in the study (Figure 1).







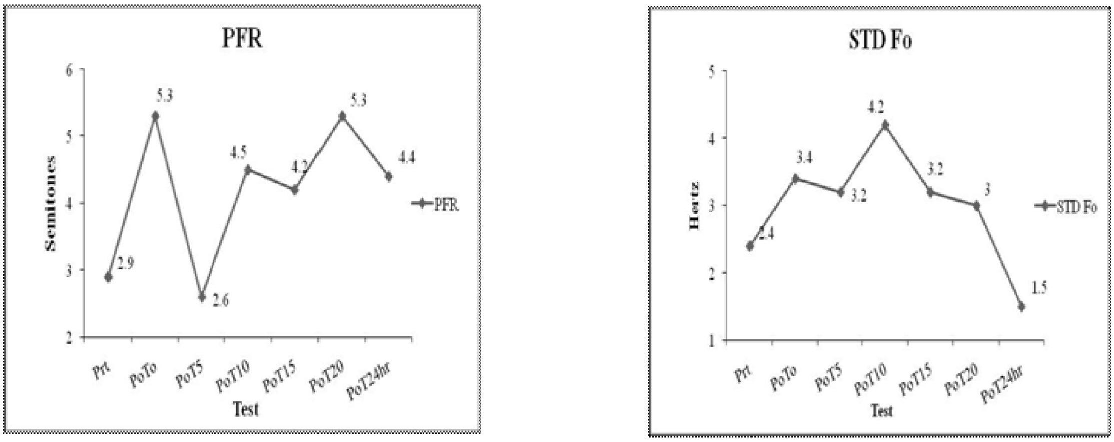
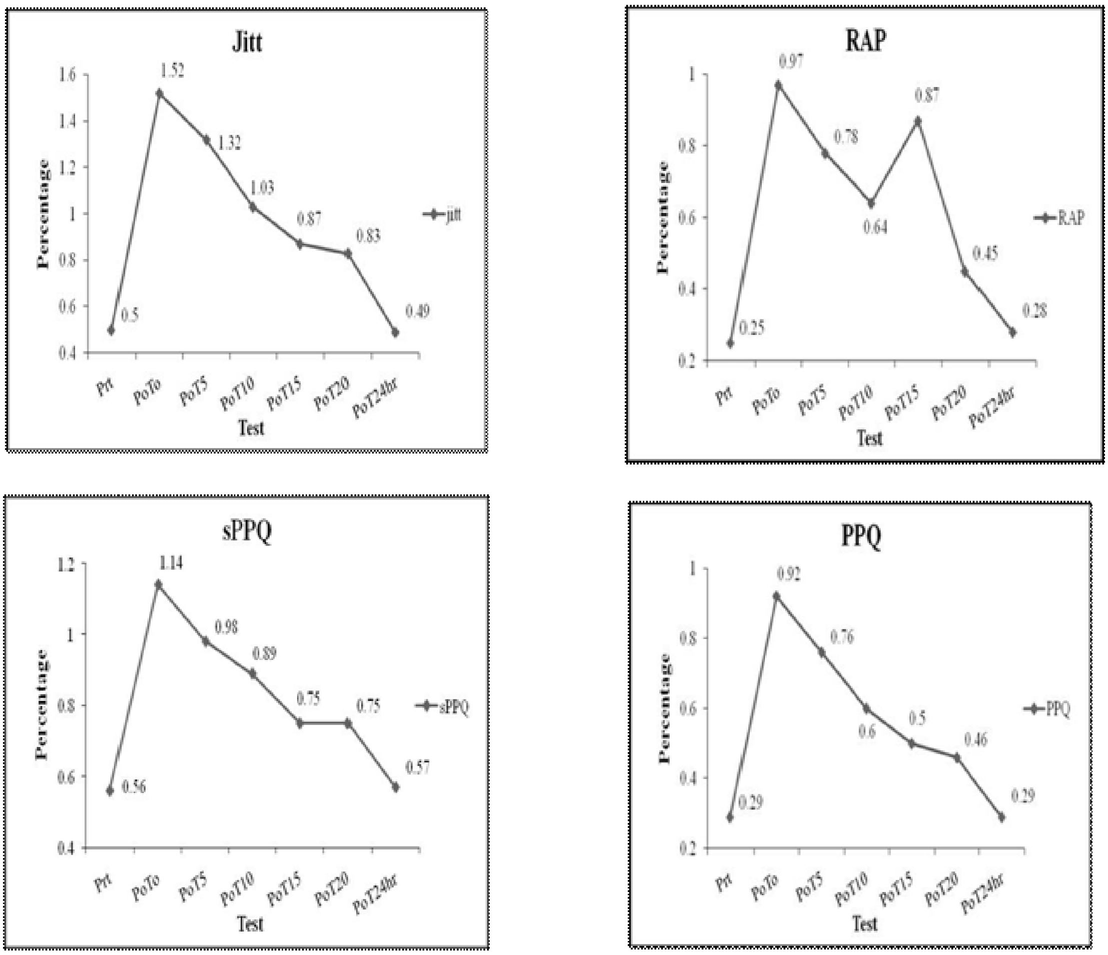


Figure 1: Voice recovery pattern of Fo, Flo, Fhi, STD Fo, and PFR.

Short and long term frequency measurements: The parameters such as Jitt, RAP, PPQ, sPPQ and jita showed significant difference from the immediate post-test to the post-test done at 20 minutes. Whereas, vFo did not reveal a significant recovery pattern. There was a significant increase in the values of the measures observed after the experimental task. And there was a subsequent recovery pattern noticed which was indicated by the returning of the values to near pre-test level within 20 minutes from the vocal loading task. The measures reached the pre-test levels at post-test done at 24 hours. This indicated that the voice parameters recovered completely after the acute physiologic change due to the vocal loading task 24 hours later (Figure 2).



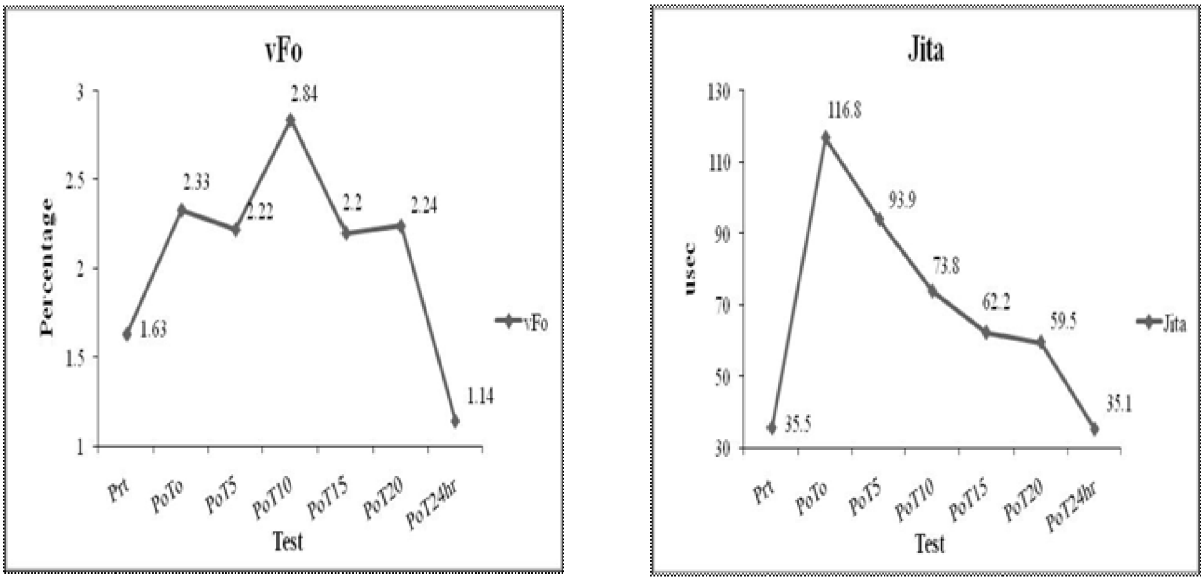
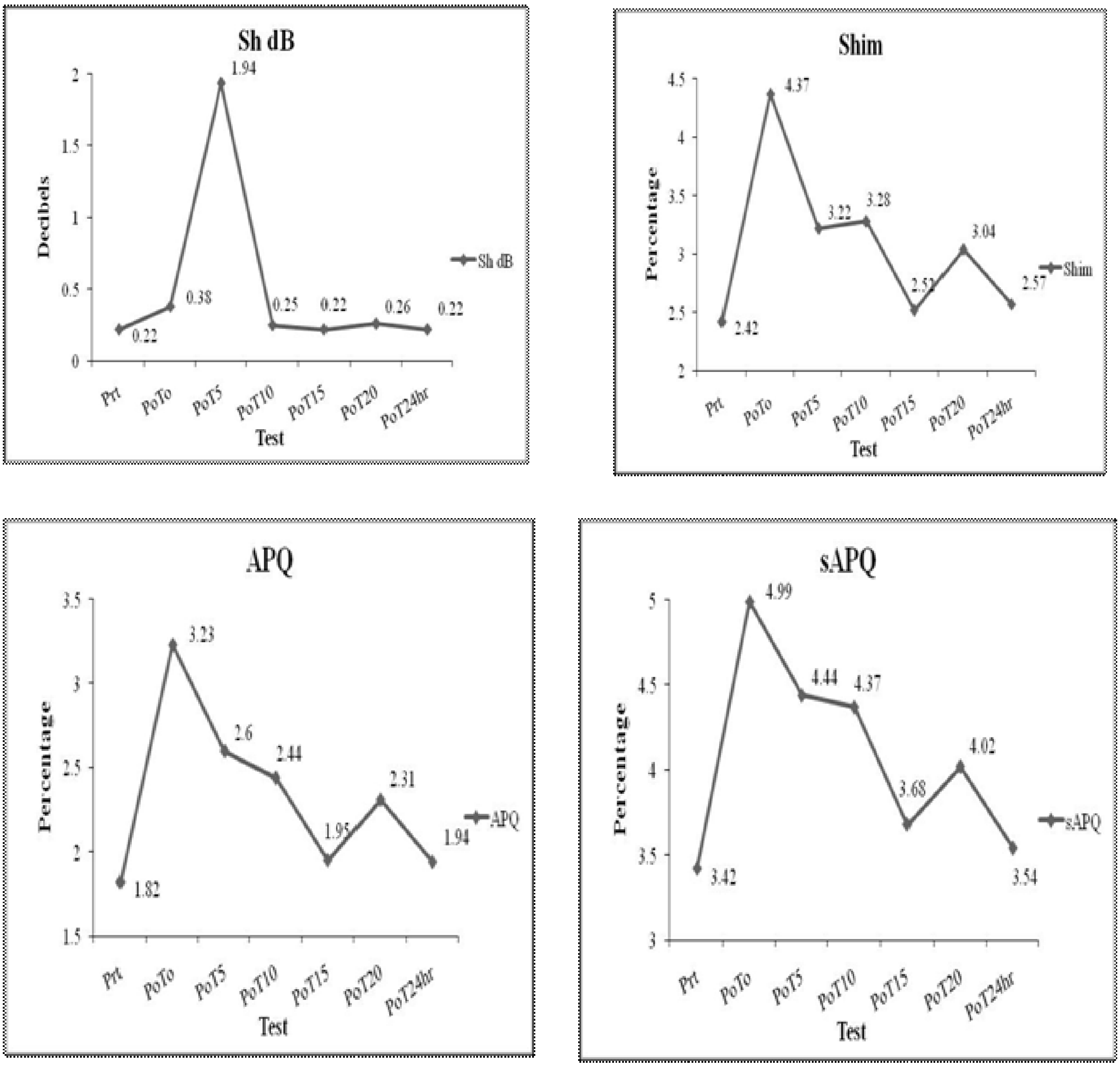


Figure 2: Voice recovery pattern of Jitt, RAP, PPQ, sPPQ, vFo, and Jita.



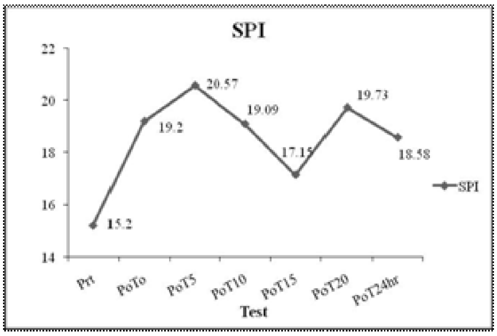


Figure 3: Voice recovery pattern of Sh dB, Shim, APQ, sAPQ, and

Noise related measures: In the noise related measures, NHR showed a significant difference from the immediate post-test to the post-test done at 20 minutes. Whereas other parameters such as SPI and VTI did not reveal a significant difference in the recovery patterns. There was significant increase in the values and there was a subsequent recovery pattern noticed which was indicated by the returning of the values to near pre-test level within 20 minutes. The values reached the pre-test levels at 24 hours post-test (Figure 4).

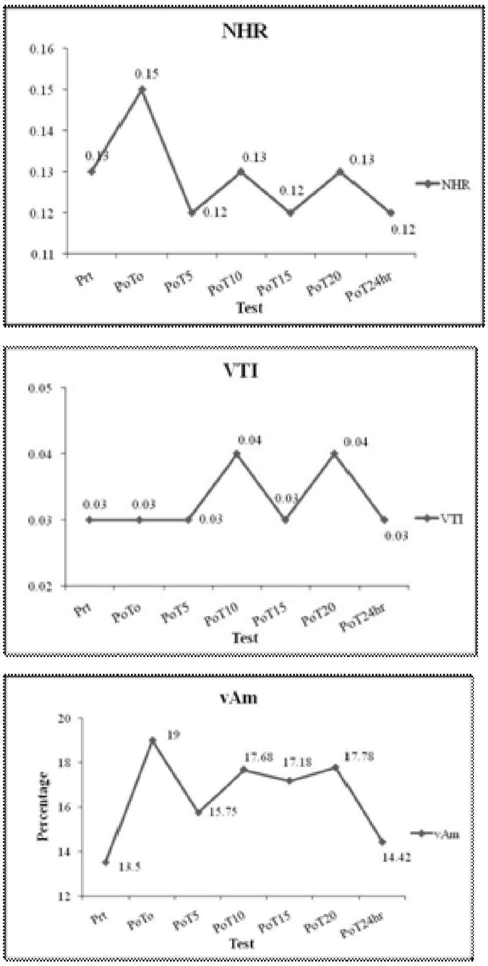


Figure 4: Voice recovery pattern of SPI, VTI, and NHR

Conclusions

The results revealed several interesting facts:

1. **Effects of vocal loading:**
   a) Changes in pitch, loudness and quality were noted after the vocal loading task. Overall voice quality change was more pronounced. Vocal loading lead to a more rough voice quality. Strain was difficult to measure.
   b) The maximum phonation time showed a significant reduction (around 6 seconds) after the vocal loading task for all the three vowels (/a/, /i/, /u/) measured. The S/Z ratio also revealed a significant increase after the vocal loading task.
   c) The acoustic analysis measured using MDVP revealed significant difference for some of the parameters. The parameters such as fundamental frequency, PFR, short and long term frequency measurements, short and long term amplitude measurements, noise and voice irregularity related measures showed significant difference after the vocal loading task.
2. **Fatigability time:** None of the subjects could sustain (75 - 80 dB SPL) loud reading task for an hour. Initial signs of fatigue were seen as early as 15 minutes. So it was concluded that normal healthy adult males could possibly sustain voice at such loudness levels not more than 30 minutes. It would be interesting to note if this sustained time would vary in women, children and with altered intensity levels.
3. Associated vocal fatigue symptoms: Majority of the subjects reported throat pain as a primary complaint along with throat tightness and running out of breath while talking.
4. Voice recovery pattern: Various acoustic parameters such as short and long term frequency measures, short and long term amplitude measures and NHR in noise related measures revealed a significant recovery pattern. This recovery was characterized by the returning of values to pre-test levels 24 hours after the vocal loading task.

The information obtained in this study ascertains that prolonged voice use can result in vocal symptoms. Complaints of vocal fatigue, voice symptoms, and voice recovery can be tracked and monitored using perceptual and acoustic measures. These findings can be applied to understand vocal endurance, susceptibility to vocal fatigue and physiological changes due to vocal loading.

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