EFFECTS OF TEACHING AND VOICE REST ON ACOUSTIC VOICE CHARATERISTICS OF FEMALE PRIMARY SCHOOL TEACHERS

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Abstract

Voice problems are known to be the most common among voice professionals worldwide. Teachers form a large group of voice professionals where females are a majority in that profession and are known to have more voice problems than males. The present study investigated the short-term effects of teaching (vocal loading) on acoustic parameters like mean fundamental frequency of phonation (pF0), standard deviation of fundamental frequency of phonation (SD pF0), speaking/reading fundamental frequency (sF0), frequency and amplitude perturbation (jitter and shimmer) and harmonic-to-noise ratio (HNR). Also, the study examined the effect of vocal rest following a workday teaching performance on these parameters. Twelve female primary school teachers in the age range of 23 to 42 years participated in the study whose average professional teaching experience was 8.6 years. The teachers were instructed to phonate vowel /a/ for 8-10 seconds at their comfortable pitch and loudness and read a standard reading passage in Kannada. These recordings were made at three different time intervals - i.e., (a) Monday morning (5-10 minutes prior to starting of teaching) - condition 1, (b) Monday evening (5-10 minutes after the school hours) - condition 2, and (c) Tuesday morning (after 17-18 hours of voice rest) - condition 3. The light-weight, portable digital audio tape (DAT) recorder was used to collect the voice and speech sample. The pF0, SD pF0, perturbation measures like jitter and shimmer and HNR were extracted from phonation of vowel /a/ and sF0 was measured from the reading sample by using PRAAT software. Results revealed that the difference between the acoustic values between condition 1 and 2 were, 14 Hz (pF0), 0.4 Hz (SD pF0), 7 Hz (sF0), 0.2% (jitter), 2.36% (shimmer) and 0.12 dB (HNR). Except HNR, all other vocal parameters increased after teaching performance (condition 2) and recovered back to baseline after 17-18 hours of voice rest (condition 3). The results indicated that these acoustic parameters (except HNR) were sensitive enough to document the extent to which the voice changes occurred due to vocal loading. Also, these altered vocal parameters were transient which recovered back to baseline after adequate voice rest.

Key words: Vocal fatigue, vocal usage, voice disorders, voice changes

Persons whose occupation places them at a high demand on vocalization are often considered to be at risk for the development of voice disorders. According to many questionnaire studies, 50% to 80% of teachers experienced voice problems (Pekkarinen, Himberg & Pentti, 1992; Gotaas & Starr, 1993) and teaching constitutes one of the 10 occupations who often require medical help for voice difficulties (Fritzell, 1996). A survey study conducted by Boominathan, Rajendran, Nagarajan, Seethapathy & Gnanasekar (2008) found 49% of high- and higher secondary Indian school teachers experienced voice problems. Voice use in teaching profession is highly demanding, and the hazardous factors are teaching often at high voice output level due to the presence of background noise, poor classroom acoustics, and poor working posture, long speaking distance, poor quality of air/ventilation,

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stress, non-availability or poor-quality aids, inadequate treatment of early symptoms, especially laryngeal infections. Contributing co-factors are gender, living habits, individual endurance, vocal skills/experiences etc. Majority numbers of primary school teachers are women and Smith, Kirchner, Taylor, Hoffman, and Lemke (1998) reported that the majority of all phoniatric voice patients were women.

One of the sources of variability in the voice loading studies was experimental conditions some being conducted in laboratory and others in field conditions. Duration of loading might be considered 11as the second variability. Studies used the shortest loading times, being 15-20 minutes (Stone & Sharf, 1973; Linville, 1995) and the longest from 45 minutes-2 hours (Neils & Yairi, 1987; Gelfer, Andrews & Schmidt, 1996). The third difference may be the loading tasks, mostly being reading task (Neils & Yairi, 1987) or naming vowels (Verstraete, Forrez, Mertens & Debruyne, 1993). On the other hand, the loading in field condition has been habitual speaking during work such as acting in a theatre play (Novak, Dlouha, Capkova & Vohradnik, 1991), or teaching at school (Gotaas & Starr, 1993).

Very few studies were reported on voice changes induced by vocal loading. Fundamental frequency, sound pressure level, perturbation measures and long-time average spectrum have been used for documenting voice changes. These studies reported contradictory results and revealed individual differences. However, the most common result is that fundamental frequency (F0) rises after loading (Gelfer, Andrews & Schmidt, 1991; Stemple, Stanly & Lee, 1995). It has been found that the fundamental frequency depend on the circumstances i.e. lower in reading samples in laboratory condition than in teaching speech in a classroom condition (Rantala, Limdhoba & Vilkman, 1998). The problem in laboratory condition is the difficulty of simulating the real-life situation. It is feasible to manipulate one or more vocal parameters under laboratory condition that cannot adequately simulate live performance. The sound pressure level and shimmer increased after loading (Vilkman, Lauri, Alku, Sala & Sihvo, 1999). Laukkanen, Ilomaki, Leppanen and Vilkman (2006) reported that the fundamental frequency of text-reading after a vocally loading workday registered a higher value compared to baseline in a group of primary school teachers. Interestingly, studies have shown that the jitter value increased (Gelfer, Andrews & Schmidt, 1991), or decreased (Stemple, Stanley & Lee, 1995) and/or showed no essential changes (Verstraete, Forrez, Mertens & Debruyne, 1993) due to vocal loading.

A very few empirical data are available on voice problems and the changes induced by vocal loading on voice parameters in Indian school teachers. Rajasudhakar and Savithri (2009a) reported increased fundamental frequency of phonation, standard deviation of fundamental frequency of phonation and jitter after one-day workload (teaching performance) in a primary school teacher. In a field study conducted by Rajasudhakar and Savithri (2009b) in five primary school teachers, reported after 6 hours of teaching, fundamental frequency of phonation, standard deviation of fundamental frequency of phonation, jitter and speaking fundamental frequency were increased compared to the pre-teaching (baseline) condition.

To the best of the knowledge, there have been very few empirical study on the teaching performance on voice in Indian school teachers in the natural-field situations. Also, the effect of voice rest after continuous, prolonged loud teaching is however not well understood. In this context, the present study documented and measured the short-term effect of changes in voice after teaching, and investigated the effect of voice rest on vocal parameters.

Method

Participants: Twelve female primary school teachers in the age range of 23-42 years (average age: 32.2 years) volunteered to participate in the experiment. Their teaching experience ranged from 5-20 years (average teaching experience: 8.6 years). They taught Science, Mathematics, Kannada, Social science and English to third and/or fourth grade students. The average number of students in each grade was about 30 to 35. The number of classes taken by the teachers per day was around five and the duration of each class was 45 minutes. The school timing was between 10 am to 4 pm including lunch time of 40 minute in afternoon. None of the participants were involved in private coaching/extra teaching after school hours. The participants were free from hypertension, diabetes, allergies, asthma and gastro-esophageal reflux disorder and did not

report of any speech, language, hearing or voice problems at the time of the study.

Instruments used: A portable, light-weight digital audio tape (DAT) recorder (Olympus digital voice recorder WS-100, Japan) was used. The recorder had in-built condenser microphone (ME 15) and the weight of the device was about 54 grams (including battery). The overall frequency response of the microphone was 100 Hz to 5000 Hz and size of the DAT recorder was about 94(L) x 40(W) x 15.1(T) mm. The sampling frequency was 12 kHz and the maximum power consumption of the DAT recorder was 100mWatts. PRAAT (Boersma & Weenink, 2009) software was used to extract some acoustic parameters of voice.

Recording procedures: The recording of voice samples was done on two regular workdays (Monday and Tuesday) after a relaxed week end. The teachers were instructed not to over use the voice on Sunday and spend the day with more voice rest and adequate sleep. Also, the same was to follow after school hours on Monday. The DAT recorder was worn around the neck of the subject. The distance between microphone and mouth was kept 10-12 cm constantly for all the participants. The subjects were instructed to phonate the vowel /a/ for 8-10 seconds at their comfortable (habitual) pitch and loudness at three different time intervals - (1) Monday morning (5-10 min prior to the starting of school i.e. condition 1, (b) Monday evening (5-10 min after the school hours i.e. condition 2, and (3) After 16-18 hours of voice rest (Tuesday morning) i.e. condition 3. Also, the subjects were instructed to read a standardized Kannada passage ('Bengaluru namma' - 42 words) after the phonation of vowel /a/. Figure 1 shows the subject wearing the digital audio tape recorder.

Acoustic analyses: PRAAT software was used to extract the acoustic parameters of voice like mean fundamental frequency of phonation (pF0), standard deviation of fundamental frequency of phonation (SD pF0), fundamental frequency of speech/reading (sF0), jitter, shimmer, and harmonic to noise ratio (HNR). The measures like pF0, SD pF0, jitter and shimmer were measured from phonation of vowel / a/. The initial and final (2 seconds) portion of the vowel phonation was truncated and the middle (4-5 seconds) steady state portion was considered for acoustic analyses. The sF0 was measured from the Kannada reading passage.

Statistical analysis: **The** mean and standard deviation of pF0, SD pF0, sF0, jitter, shimmer, and HNR were calculated from twelve teachers at three conditions. Repeated measures of ANOVA was administered to check the differences across conditions and Bonferroni's multiple comparison was done to test the pair-wise differences.

S.No.	Parameters	Condition 1		Condition 2		Condition 3	
		Mean	SD	Mean	SD	Mean	SD
1	pF0 (Hz)	194	20	208	31	193	21
2	SD pF0 (Hz)	1.61	0.63	2.01	0.71	1.52	0.62
3	sF0 (Hz)	203	20	210	21	202	21
4	Jitter (%)	0.53	0.23	0.73	0.45	0.47	1.4
5	Shimmer (%)	10.41	5.25	12.77	4.62	10.01	4.3
6	HNR (dB)	14.36	4.96	14.48	3.27	13.02	4.3

Table 1. *Mean (M) and standard deviation (SD) of frequency, perturbation and HNR measures of teachers*

Figure 1: Subject wearing the digital audio tape recorder.

Results

The mean fundamental frequency of phonation (pF0) of vowel /a/ in condition 1 was 194 Hz. The pF0 value rose to 208 Hz at the end of the day (condition 2). After 18 hrs of voice rest, pF0 was dropped to 193 Hz. The mean and standard deviation of acoustics measures across three conditions were tabulated in table1.

Results of repeated measures of ANOVA revealed significant difference across the conditions at 0.001 levels on pF0 [$F(2,22)=11.134$, $p<0.001$]. Results of Bonferroni's multiple comparison revealed that there was significant difference between condition 1 and 2, and between condition 2 and 3. But, no significant difference was noticed between condition 1 and 3. The standard deviation of fundamental frequency of phonation (SD pF0) was 1.61 Hz in condition 1. The SD pF0 increased to 2.01 Hz in condition 2 and droppe d to 1.52 Hz in condition 3. Results of repeated measures of ANOVA revealed significant difference across conditions at 0.001

levels on SD pF0 [F(2,22)=15.237, p<0.001].Results of Bonferroni's multiple comparison revealed significant differences between condition 1 and 2, and condition 2 and 3. But, no significant difference was noticed between condition 1 and 3.

The mean fundamental frequency of speaking/ reading (sF0) in condition 1 was 203 Hz. The sF0 rose to 210 Hz at the end of the day (condition 2). After 18 hrs of voice rest, sF0 dropped to 202 Hz. Results of repeated measures of ANOVA revealed significant difference across the conditions at 0.001 levels on sF0 [F(2,22)=11.412, p<0.001]. Results of Bonferroni's multiple comparison revealed significant differences between condition 1 and 2, and between condition 2 and 3. But, no significant difference was noticed between condition 1 and 3.

Jitter, in condition 1 was 0.53% which increased to 0.73% after 5 to 6 hours of teaching (condition 2). After 17/18 hours of voice rest, jitter dropped to 0.47%. Results of repeated measures of ANOVA revealed significant differences across the conditions at 0.001 levels on jitter [F (2,22)=9.217, p<0.001]. Results of Bonferroni's multiple comparison revealed significant differences between condition 2 and 3 only.

In condition 1, shimmer was 10.41% and it increased to 12.77% after teaching performance (condition 2). In condition 3, (after voice rest) the shimmer value decreased to 10.01%. Results of repeated measures of ANOVA revealed significant differences across the conditions at 0.001 levels on shimmer [F(2,22)=6.040, p<0.001]. Results of Bonferroni's multiple comparison revealed significant differences between condition 2 and 3 only. Before the starting of the teaching day, the mean HNR was 14.36 dB (condition 1) and it was 14.48 dB at the end of the teaching day (condition 2). After voice rest, i.e., on the next morning, it was 13.02 dB in condition 3. Results of repeated measures of ANOVA revealed no significant difference across the conditions on HNR measure.

Discussion

The results showed that the frequency related measures like pF0, SD pF0 and sF0 were significantly higher in condition 2 compared to condition 1. The results indicated that the frequency related parameters were increased from condition 1 to 2 by 14 Hz for pF0, 0.33 Hz for SD pF0, and 7 Hz for sF0. Compared to any other profession, teachers often speak loudly for longer duration in presence of high level background noise and not in a conducive environment. Due to this, most of the teachers suffer from vocal fatigue at the end of the workday. The accompanying feature along with vocal fatigue would be an increase in the level of muscular and structural tension of the vocal folds as reported by Welham and Maclagan (2003), thus leading to a higher F0 value. The obtained results are in agreement with the findings of Rantala, Vilkman and Bloigu (2002) who reported that the F0 increased by 9.7 Hz between the first and last lesson and also SD pF0 after loading. Rajasudhakar and Savithri (2009a) who reported that the F0 increased about 7.24 Hz between the first class recording and last class recording in a workday.

The literature offered two explanations for the F0 rise. According to Stemple, Stanley and Lee (1995), increased F0 is a consequence of weakness of the thyroarytenoid muscle. When the muscular layer of thyroarytenoid muscle slackens, the cover and transition layers of the vocal folds stiffens. This leads to an increase in the rate of vibrations in the vocal folds and hence a rise of the F0. Vilkman, Lauri, Alku, Sala and Sihvo (1999) have suggested another explanation. The increased F0 was caused by the speaker's compensatory reactions to alterations in their voice. When compensating for the physiological changes, which could be alterations in the mucosa, the speaker increases the frequency of vocal fold vibration and the glottal adductory forces. This increased constriction influenced the F0 indirectly. It increases the sub-glottal pressure, which adds tension to the vocal folds and, consequently raised the F0.

The pF0, SD pF0, and sF0 dropped significantly from condition 2 to condition 3. After 17 to 18 hours of voice rest, the measured acoustical parameters were the same as in condition 1. The present results supported the findings of Jayaram and Kalaiselvi (2006) who reported that there was reduction in frequency measures after 12 hours of complete voice rest following vocal loading (yakshagana performance).

The perturbation measures like jitter and shimmer also increased significantly from condition 1 to condition 2 by 0.23% and 2.63%, respectively.

Gelfer, Andrews and Schmidt (1991) and Rantala, Vilkman and Bloigu (2002) reported similar findings that jitter value increased after vocal loading. Also, shimmer increased after loading (Vilkman, Lauri, Alku, Sala & Sihvo, 1999; Rantala & Vilkman, 1999). The jitter and shimmer values which increased from condition 1 to 2, reduced significantly from condition 2 to 3. This reduction would be attributed to 17-18 hours of vocal rest wherein, the vocal folds and the surrounding laryngeal regions regained blood supply. Also, the resting of vocal apparatus brought about a reduction in structural and muscular tension of vocal folds, thereby controlling the variations in the vibration of vocal folds.

Harmonic to noise ratio (HNR), is one of the noise related measure. Interestingly, it did not show any significant changes across conditions. The results of the present study is in consonance with the findings of Verstraete et al., (1993) who found no significant changes in HNR value following 60 minutes reading task in untrained voice users. But, the present findings did not support the findings of Jayaram and Kalaiselvi (2006) who reported increased HNR after Yakshagana performance (vocal loading). This needs to be studied in a larger group of teachers to make any conclusions.

Summary and conclusions

The study measured the effects of teaching performance and voice rest on acoustic voice parameters in primary school teachers. The analysis of speech and voice samples of 12 primary school teachers' revealed that the frequency related measures like, pF0, SD pF0 and sF0 along with perturbation measures like jitter and shimmer increased after 6 hours of voice use (classroom teaching). After 17-18 hours of voice rest, following the vocal loading, the increased voice parameters dropped and it reached to pre-teaching (baseline) condition. HNR did not show any characteristic 'trend'/changes after performance and after voice rest. It can be concluded that the acoustic voice parameters (except HNR) are sensitive enough to document the short-term effect of teaching on voice. The importance of voice rest and its concomitant effect on voice features was positive i.e., it recovered to the baseline value. So the changes induced by short vocal loading are transient and it can be brought back to normal (baseline) after adequate voice rest. The results of the present study may augment the knowledge for speech-language pathologists in counseling the professional voice users on voice usage, voice changes consequent to vocal loading and its short- and long-term effect on voice etc, in general and particular in teachers.

Future directions: The study can be administered on large number of teachers and can include male teachers to examine gender differences. Also, the same method can be employed to study differences between trained and untrained voice users. The study can be done by manipulating the rest period at different intervals of time. Acoustic analyses of voice can be coupled with aerodynamic, or electro-myographic measures to document the changes due to vocal loading.

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