

An Analytical Study of Age and Gender Effects on Voice Range Profile in Bengali Adult Speakers using Phonetogram

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ABSTRACT

The study was aimed to analyze the changes in acoustic parameters based upon age and gender effects and to obtain normal voice range profile (VRP) of adult male and female of three different age range. Total no. of 90 subjects were grouped into three groups as per their age (20-30, 40-50 and 60-70 years) consisting 15 males and 15 females in each group. All participants were native Bengla speakers, not reported to have any speech, language, hearing, respiratory, or any other motor/ sensory deficits. Dr. Speech Software Phonetogram (version 4) and SPSS software (version 11.0) were used as tools. VRP parameters such as maximum and minimum fundamental frequency (F₀), fundamental frequency range, sound pressure level (SPL), semitone and area were measured. Subjects were asked to phonate /a/ vowel in seven consistent registering in normal loudness. The mentioned parameters were measured by the tools. Responses were statistically analyzed by SPSS software (version 11.0). There was significant difference in fundamental frequency of males and females. But, there were no such significant difference in other parameters. For females endochronological changes results in more massive vocal folds and consequently, reduced F₀ in old age group. Elderly males had a significantly higher F₀ than young and middle aged due to vocal cord atrophy and tissue stiffening. In daily practice, the clinician prefers to make use of visual tools to treat the patient with voice problem.

Keywords: Phonetogram, Voice range profile (VRP), Bengali speakers.

INTRODUCTION

The human voice is unique in all of the animal kingdom and is the fundamental method of human communication. The range of frequency and flexibility of sound production allows the voice to express emotions of human soul. As baby grow the size of the larynx and vocal folds increase, the fundamental frequency decreases. In the teenage years, at puberty, the larynx of males grows considerably, and this growth is associated with nearly one octave of lowering of pitch. The larynx and vocal cord tissues do not fully mature until late adolescence. Hormone related changes are particularly noticeable among boys. The rapid changes in the size and character of larynx causes characteristic pitch breaks and voice “cracking” during puberty.

After several decades of relatively stable voice, noticeable changes can occur in the later years of life. Structural and physiological changes are said to be contributing factors for these changes in vocal parameters with age. At approximately the age of 18, the voice is adult-like and remains consistent until approximately 60 years of age when age related deterioration begins. Male voices go up in pitch after age 60, reflecting atrophied (shrinking) vocal folds. Some female voices go down in pitch with advanced age, reflecting thickening of

vocal folds related to hormonal changes; other female voices go up in pitch, reflecting atrophy of vocal folds. Voices may also become hoarse and tremorous with age, reflecting both muscle atrophy and age-related deterioration in neurological control of larynx.^{20,24} In women, the epithelium may progressively increase with aging, particularly age 70.⁷ In elderly men, the mucosa stiffens and increases in viscosity in comparison with women and younger men,¹¹ resulting in decreased ease of phonation.^{1,11}

In males, the structural changes in the vocal mechanism are more evident than females. The vocal changes in males occur around age 60. Men’s voices lower until age 40 to 50 years, and rise with increasing age. Average fundamental frequency also rises.

Several software programs have been developed to measure and plot intensity range against fundamental frequency range (F₀) on a simple x-y scale. Phonetogram or voice range profile (VRP) is one of those, this allows the patient and clinician to measure and compare changes in vocal fold dynamics over time.

Phonetogram is a graph of intensity range vs the fundamental frequency range of phonation for a particular person.^{2-4,15,23}

The VRP is a graphical representation that reflects a speaker’s ability to produce maximum and minimum frequency

range of phonation under controlled conditions of vowel production and mouth opening.²¹

Several studies focus on the different characteristics of the VRP, such as highest and lowest frequency and intensity.^{2,4,17} Separate characteristics, such as the highest frequency or lowest intensity, may indeed be hampered by diseased vocal folds, but these characteristics have a low sensitivity and specificity. Some authors have successfully attempted to circumvent this difficulty, but introducing an index that contains more variables at the same time by increasing the specificity and sensitivity.⁵ Studies based on VRP will further lead to a better understanding of the phenomenon.

The need of the study is to develop an acoustic interpretation of the shape of the VRP to set some answer from the question that what are the primary physiological mechanism for changing sound pressure level and fundamental frequency and critical data on human are missing. It is anticipated that a better understanding on the VRP will be helpful in guiding strategies for the guidance and treatment of voice disorders.

The present research aimed to analyze the changes in acoustic parameters, such as maximum fundamental frequency (max F_0), minimum fundamental frequency (min F_0), fundamental frequency range, sound pressure level (SPL), semitone and area based upon age and gender effects.

METHODS

Participants

A total of 90 individuals participated in the study, which were divided into three groups, 1st group (15 male and 15 female adults with age range between 20-30 years), 2nd group (15 male and 15 female adults with age range between 40-50 years) and 3rd group (15 male and 15 female adults with age range between 60-70 years). All the participants were native Bengla speakers, not reported to have speech, language, hearing, respiratory and any other sensory/motor deficits. The entire female subjects should be excluded from influence of menstrual cycle.

Tools

Phonetogram was registered using Dr Speech University special software (version 4). Manufacturer: Tiger DRS, Inc.

All statistical analysis were performed using the software package for social sciences (SPSS) version 11.0 computer software.

Parameters

Maximum fundamental frequency (max. F_0), minimum fundamental frequency (min. F_0), fundamental frequency range, maximum sound pressure level (SPL), minimum sound pressure level (SPL), sound pressure level range, semitone and area.

Procedure

Firstly calibration was done through Sound Level Meter. The direction and distance (30 cm) of the subject's mouth to the

microphone are carefully controlled during the procedure. Subjects are tested using the vowel /a/. The mean fundamental frequencies were determined by asking the subjects to phonate /a/ in seven consistent registering (after several training with seven singing registers in their natural scale) in normal loudness.⁶ The subjects were instructed to produce phonation at the physiologic boundaries, without, of course, injuring the voice during phonation at the extreme registers.

The microphone collects the voice sample and sends it via the sound cards in a digitized form. The Dr speech software, using a manufacture defined algorithm, extracts the F_0 and SPL information from the sample and creates the voice range profile which is displayed on the computer screen.

The above-mentioned parameters were extracted from the data and taken into consideration the terms of their relevancy in reflecting voice range profile over other parameters.

Statistical Analysis

Central tendency (arithmetic mean) and dispersion (standard deviation) for each phonetogram parameter for each parameter in each group were measured. One-way analysis of variance (ANOVA) test for each of the eight parameters were measured among three age groups. In each ANOVA table, both between group and within group variability were analyzed at 95% level of significance for this different age group. For each ANOVA table, a post-hoc analysis of multiple comparisons between each of three groups using the LSD method was done to find out the level of significance of mean differences between each two subsequent groups at 95% level of significance. The t-test was done to find out the level of significance of mean differences in terms of phonetogram parameters between males and females. All statistical analysis were performed using the SPSS software (version 11.0).

RESULTS

Fundamental Frequency (F_0)

Result of the study indicated mean value of F_0 was highest in geriatric population followed by adult age and least value obtained with younger age for males. Result for the female groups indicated that there was increase in fundamental frequency with advancing age from young, through middle age to old.

As shown in Table 1, the mean F_0 maximum were 172.800, 193.2000 and 224.4000 Hz for 1st, 2nd and 3rd groups respectively, mean F_0 minimum were 122.0000, 103.9333 and 121.0667 Hz respectively and mean F_0 range were 50.8000, 89.2667 and 103.3333 Hz respectively. ANOVA reveals that for all three parameters of F_0 , at $p < 0.05$ level of significance, there was at least one inequality of mean among three groups [$F = 12.407 > F(0.05) = 0.000$], [$F = 7.284 > F(0.05) = 0.002$], [$F = 31.976 > F(0.05) = 0.000$] for F_0 max., F_0 min., F_0 range respectively. Hence, there is a significant difference in maximum

Table 1: Mean, SD and p-values of fundamental frequency of males and females with respect to age

Parameters	Groups	Male			Female		
		Mean	SD	p	Mean	SD	p
F ₀ max.	1st	172.8000	23.87826	0.000	385.5333	12.78876	0.000
	2nd	193.2000	8.29974		351.8667	42.33348	
	3rd	224.4000	42.54880		317.1333	58.64039	
F ₀ min.	1st	122.0000	13.984	0.002	221.2667	13.06285	0.015
	2nd	103.4333	4.905		212.6667	20.50668	
	3rd	121.0667	20.485		203.3333	13.76158	
F ₀ range	1st	50.8000	16.15196	0.000	164.9333	16.04666	0.010
	2nd	89.2667	8.69702		139.2000	46.93491	
	3rd	103.3333	26.53748		139.4000	57.24609	

Table 2: The multiple comparisons of F₀ for males and females with respect to age

Dependent variables	Groups	Significant difference at 95% level of confidence	
		Male	Female
F ₀ max.	1st and 2nd	0.057	0.035
	2nd and 3rd	0.005	0.030
	1st and 3rd	0.000	0.000
F ₀ min.	1st and 2nd	0.002	0.152
	2nd and 3rd	0.003	0.004
	1st and 3rd	0.862	0.121
F ₀ range	1st and 2nd	0.000	0.115
	2nd and 3rd	0.000	0.002
	1st and 3rd	0.000	0.114

fundamental frequency and fundamental frequency range among three age groups of male, with the values increasing with age. But the minimum fundamental frequency of the young age groups has the highest mean value followed by geriatric population followed by the young adult groups. For females, mean F₀ max. were 385.5333, 351.8667 and 317.1333 Hz for group 1st, 2nd and 3rd groups respectively and mean F₀ min. were 221.2667, 212.6667 and 203.3333 Hz respectively and mean F₀ range were 164.9333, 139.2000 and 139.4000 Hz respectively. ANOVA reveals that for all three parameters of F₀ at p < 0.05 level of significance, there was at least one inequality of mean among three age groups [F = 9.758 > F(0.05) = 0.000], [F = 4.638 > F(0.05) = 0.015], [F = 5.207 > F(0.05) = 0.010]. Hence, an overall trend of an increase in F₀ with advancing age from young, through middle age to old exist in female voice.

From LSD post-hoc analysis for multiple comparison, as shown in Table 2, maximum fundamental frequency for males between 2nd and 3rd groups (p = 0.005), between 1st and 3rd groups (p = 0.000) and tends toward significance between 1st and 2nd groups (p = 0.057). Also there was a significant difference of minimum fundamental frequency between 1st and 2nd groups (p = 0.002) and between 2nd and 3rd groups (p = 0.003) but there was no significant difference between 1st and 3rd groups (p = 0.862). There was a significant difference of fundamental frequency range between 1st and 2nd groups (p = 0.000), between 1st and 3rd groups (p = 0.000) and between 2nd and 3rd groups (p = 0.045). Therefore, the fundamental

frequency was highest in geriatric population followed by adult age and least value obtained with younger age for three age groups of male. The results also revealed that there was a significant difference for maximum fundamental frequency for females between 1st and 2nd groups (p = 0.035), between 1st and 3rd groups (p = 0.000), and also between 2nd and 3rd groups (p = 0.030) with F₀ maximum decreasing significantly with increasing age range for female. For minimum F₀, no significant difference existed between 1st and 2nd groups (p = 0.152), and 2nd and 3rd groups (p = 0.121) of females but there was a significant difference between 1st and 3rd groups (p = 0.004). Hence, the F₀ minimum also tends to decrease significantly in elderly group than young females. There was no significant difference of fundamental frequency range between 1st and 2nd groups of females (p = 0.115), between 2nd and 3rd groups (p = 0.114). However, there was a significant difference present between 1st and 3rd groups (p = 0.002). So, F₀ decreasing significantly in the elderly females as compared with young females. Thus, an overall trend of an increasing fundamental frequency with advancing age from young, through middle age to old exists in female voice. So, in females, the fundamental phonational frequency is greater than males.

Sound Pressure Level (SPL)

As shown in Table 3, the values of SPL ANOVA reveal that out of three parameters of SPL, there is at least one inequality of mean among three age groups [F = 8.300 > F(0.05) = 0.001],

[$F = 7.528 > F(0.05) = 0.002$], [$F = 0.282 < F(0.05) = 0.756$] for the two parameters of maximum and minimum sound pressure level at $p < 0.05$ level of significance. However, there was no significant difference between the three age groups for sound pressure level range for male. For females, ANOVA reveals that for all three parameters of SPL, at $p < 0.05$ level of significance there was at least one inequality of mean among three age groups [$F = 4.453 > F(0.05) = 0.017$], [$F = 4.527 > F(0.05) = 0.008$], [$F = 5.364 > F(0.05) = 0.018$].

From LSD post-hoc analysis for multiple comparisons as shown in Table 4 reveals that the changes of SPL were not simply linear for both males and females. SPL shows a marked trend to decrease with increasing age, especially for the geriatric population for males. For females although significant difference were found sporadically between certain groups, but no definite preponderance of age effects on vocal intensity was noted. Slight decrease in SPL at middle age group (2nd group) in female was noted in SPL maximum and SPL minimum.

Semitone and Area

There were no significant difference found in these two parameters semitone and area.

So, from Table 5, for semitone of males ANOVA revealed at $p < 0.05$ level of significance there was at least one inequality of mean among these three age groups [$F = 2.659 < F(0.05) = 0.082$]. For females in the area of semitone, inequality was $F = 3.123 > F(0.05) = 0.054$. For the parameter of area inequality for male group was $F = 0.612 > F(0.05) = 0.547$ and for female

group inequality from ANOVA result was $F = 11.960 > F(0.05) = 0.000$. There was a significant difference in semitone for 1st and 3rd groups of males and females in Table 6. So, result showed a gradual trend to decrease in semitone with increasing age for both males and females. For the parameter of area there was a significant difference of means between 1st and 2nd groups, 2nd and 3rd groups and 1st and 3rd groups though not significant at 0.05 level of significance from the Tables 5 and 6 in males. So, there was an increase of area in young adult followed by geriatric population for male. For female the result revealed that there was a significant difference of means between the age groups (1st and 2nd) and (2nd and 3rd) at p-value of (0.000 of first group, i.e. 20-30 yrs), (0.000 of second group, i.e. 40-50 yrs) and significant difference between the age groups (1st and 3rd) (0.960 of 3rd group, i.e. 60-70 yrs). Thus, result demonstrated that the middle-aged females have greater vocal efficiency than both young and elderly female.

DISCUSSION

Comparing the age groups of the present study with those of the above-mentioned studies, it can be well established that elderly adults of age limit above 55 to 60 years had significantly higher F_0 (both max and min) than young adults of age limit of 30 to 35 years. Moreover, due to the division of the age groups, a significant raising of F_0 was also reported in the middle age group (40-50 yrs) in which age the geriatric physiological changes in the phonatory system was said to commence.²⁵ For

Table 3: Mean, SD and p-values of SPL of males and females with respect to age

Parameters	Groups	Male			Female		
		Mean	SD	p	Mean	SD	p
SPL max.	1st	107.2133	13.13490	0.001	105.7467	14.49615	0.017
	2nd	90.9533	4.14485		91.9600	8.48265	
	3rd	98.1000	13.05319		101.4333	14.56868	
SPL min.	1st	100.6867	14.32988	0.002	96.8933	15.11000	0.008
	2nd	84.8467	5.31709		82.3933	8.38702	
	3rd	92.4533	11.89723		96.0533	16.03834	
SPL range	1st	6.5267	2.98483	0.756	7.6600	4.30213	0.018
	2nd	6.1067	3.29135		9.5667	3.42400	
	3rd	5.6400	3.46117		5.3600	3.82158	

Table 4: The multiple comparisons of SPL in males and females with respect to age

Dependent variables	Groups	Significant difference at 95% level of confidence	
		Male	Female
SPL max.	1st and 2nd	0.000	0.005
	2nd and 3rd	0.028	0.050
	1st and 3rd	0.081	0.363
SPL min.	1st and 2nd	0.000	0.006
	2nd and 3rd	0.069	0.009
	1st and 3rd	0.050	0.867
SPL range	1st and 2nd	0.724	0.184
	2nd and 3rd	0.695	0.114
	1st and 3rd	0.457	0.111

Table 5: Mean, SD and p-values of semitone and area in males and females with respect to age

Parameters	Groups	Male			Female		
		Mean	SD	p	Mean	SD	p
Semitone	1st	7.4667	2.06559	0.082	9.6667	1.04654	0.054
	2nd	7.2000	4.31277		8.6667	2.69037	
	3rd	5.0000	2.85357		7.4000	3.2026	
Area	1st	12.9000	7.13853	0.547	11.9667	6.35831	0.000
	2nd	14.6800	10.81019		26.0533	8.87371	
	3rd	11.0333	8.76573		12.1333	11.25152	

Table 6: Multiple comparisons of semitone and area in males and females with respect to age

Dependent variables	Groups	Significant difference at 95% level of confidence	
		Male	Female
Semitone	1st and 2nd	0.821	0.278
	2nd and 3rd	0.042	0.017
	1st and 3rd	0.068	0.171
Area	1st and 2nd	0.592	0.000
	2nd and 3rd	0.275	0.960
	1st and 3rd	0.574	0.000

females, endochronological changes results in more massive vocal folds and consequently, reduced F_0 for women.^{10,22} For the contrastive findings, results are also supported with study of Sulter, Schutte and Miller (1995)⁹ who found greater frequency range (157.3 to 1223.7 Hz) in females than in males (86.1 to 785.4 Hz). Similar findings were reported earlier by Hollien, Dew and Philips (1971)¹² mean values for the lowest and highest frequencies of phonation were 78 and 698 Hz for the males and 139 and 1108 Hz for females. Naturally, females have higher phonational frequency than the males.

There was no significant difference in sound pressure level (SPL). Coleman, Mabis and Hinson (1977)¹³ found the sound pressure level maximum values for their group of young adults (age range 21-34 yrs for males and 20-39 yrs for females) to 126 dB for males and 122 dB for females, and sound pressure level for minimum of 51 dB and 44 dB for males and females respectively. SPL ranges were 54.8 dB for males and 51 dB for females. These values were close to the ones derived in the present study.

There was no significant difference in the semitone. Ramig and Ringel (1983)¹⁹ found the mean phonational range for semitone in three groups (young, middle and old age) of males. Their data revealed, though not statistically significant, age-wise differences do exist for phonational range: semitones decreasing with increasing range (Ptacek, Sander, Malone, Jackson 1966).¹⁴ In the parameter for semitone for female the result is supported by Honzo and Isshki (1980)¹⁶ who stated that voices for older women are perceptually rough and hoarse when compared to that results in reduced pitch range. Gender effect does not exist, at least for phonational frequency range in semitones.⁸

The present study demonstrated that there is no significant difference in area per age and gender effects. A probable argument was that underlying vocal compensatory mechanisms in the elderly might contribute in keeping the overall VRP

unchanged. However, according to Sulter Schutte, Miller (1994)¹⁸ lack of quantitative knowledge about what constitutes a "normal" area results in quantitative judgment with imaginary frame of references.

CONCLUSION

The present study is an attempt toward exploring the usefulness of VRP in Indian context. From the present study, it can be concluded that in daily practice the clinician prefers to make use of visual tools to treat the patient with voice problem as, there age-related changes in some aerodynamic and time-based phonatory measures, it is important to account for the variable of age when assessing vocal pathology. A calculation of a normative voice range profile is to compare individual's voice range profile with this norm in order to make a statement about the degree of pathology of a patient's voice and to evaluate therapeutic outcomes. Different vocal cord disorders should be taken up to infer the age-related pathological changes of larynx and vocal cords for further study. As well as, phonetogram results should be correlated with various aerodynamic studies.

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