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ORIGINAL ARTICLE

Estimation of Spectral Amplitude Measures in Healthy Aged Individuals

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ABSTRACT

Introduction: The anatomical and physiological changes in the phonatory system due to aging have a major impact on voice. Widely researched parameters of voice like fundamental frequency and the perturbation measures have strong correlation with age. However, these measures depend on the location of the exact pitch pulses and it may yield unreliable results in case of a severely aperiodic voice. Also, harmonic measures of voice in healthy aging are scanty in the literature.

Aim: The present study focused on determining the changes in harmonic-related measures in healthy aging individuals using spectral amplitude measures.

Materials and methods: The participants were classified into three groups as young, middle-aged, and elderly adults based on their age. All the participants were required to sustain three different types of vowels. Voice samples were analyzed using CSL software to obtain the spectral amplitude measures.

Results: This showed that there was a decrease in spectral amplitude measures with aging.

Discussion: Thus, suggesting that the harmonic structure of voice is not affected in healthy aged individuals. Vowel type and gender also influences the harmonic-related measures in the healthy aging population.

Conclusion: The results of the present study could be used by the voice clinicians while assessing adults with voice disorders. It will also help the clinicians in delineating the age and gender differences in the vocal parameters.

Keywords: Healthy aging, Spectral amplitude measures, Voice quality.

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INTRODUCTION

The normal process of aging has a major impact on the voice. It changes the anatomical and physiological mechanism of the phonatory system. These changes include atrophy of the laryngeal muscles,[1] ossification and calcification of the cartilages of larynx,[2] thinning of vocal fold mucosa,[3] reduction in the movement of the cricothyroid joint.[4] Most of the researchers have agreed that these age-related anatomical and physiological changes in voice affect the acoustic properties of speech.[5,6] Fundamental frequency is one of those acoustic properties that are most widely studied in healthy aged individuals. In women, F0 remains considerably the same until menopause, after which the pitch decreases by 10 to 15 Hz. This decrease could be attributed to the hormonal changes leading to edema of the mucosa. In men, F0 rises considerably after middle age (approximately 35 Hz).[7,8]

Other widely researched parameters are frequency and amplitude perturbation measures. These signify the cycle to cycle variations in the pitch period and amplitudes respectively. These measures of periodicity are known to determine the vocal control and are the aspects that are most often studied in aging voice.[9] It was observed that jitter and shimmer measures are increased in both male and female elderly individuals. Moreover, shimmer is found to be strongly associated with age.[10] However, these measures are reported to be less reliable because of their dependency on the exact location of the pitch pulses, which could lead to an uncertain result in case of a severely aperiodic voice.[11,12]

Spectral dependent measures like the normalized noise energy, cepstral analysis and the spectral amplitude measures are found to capture the harmonic organization of the spectrum and estimate the periodicity of voice based on the harmonics. Spectrum is one of the ancient methods of acoustic voice analysis, revealing both voice source and formant characteristics. A spectrum is obtained by subjecting the waveform obtained to fast Fourier transformation. Spectrum analysis gives representative information on voice timbre. The breathy and the hoarse quality of voice can be easily detected using the vowel spectra analysis.[13,14] Once the spectrum is obtained, the amplitude of the first two harmonics (H1 and H2 respectively) and the first three formant frequencies

(A1, A2 and A3 respectively) will be determined and a comparison between the amplitudes will be made. A comparison between the first two harmonics will give information about the open phase of the glottal pulse. The comparison between the amplitude of first harmonic and the first formant indicates the first formant bandwidth. The information regarding the spectral tilt at mid frequencies can be known by comparing the amplitudes between the first harmonic and the second formant frequency. And the spectral tilt at the higher frequencies can be known by comparing the amplitudes of the first harmonic and third formant frequency.[13,14] The larger amplitude differences indicate the presence of a breathy voice and smaller amplitude differences indicate the presence of creaky quality of voice. These measures are less susceptible to the technical shortcomings that are faced by the perturbation measures[11] and better depict the harmonic organization. Hence, the present study focused on characterizing the harmonic structure of the voice in the adults through spectral amplitude measures.

Age-related changes in voice have been extensively studied on fundamental frequency and perturbation measures of voice. However, because of poor reliability on these measures, it is difficult to estimate the exact changes that take place with aging. Also, the evidence related to harmonic structure of voice of elderly individuals is scanty. Thus, the present study is carried out to determine the changes in the harmonic-related measures of voice with aging. Furthermore, the results of the study will help the voice clinicians in distinguishing the aging voice from that of the disordered voice and helps in the better assessment and management of voice in elderly population. Thus, the aim of the study was to estimate the spectral amplitude measurements of voice in healthy-aged population.

MATERIALS AND METHODS

Participants

A total of 120 participants were recruited for the study. They were divided into three groups based on the WHO age classification. Each group consisted of 40 adults (20 males and 20 females) in which group 1 had adults between the age of 18 and 40 years, group 2 had adults between the age range of 40 and 60 years and group 3 had adults between the age range of 61 and above. All the participants included in the study were adults having normal voice and none of them had any voice problems, history of vocal abuse or misuse, gastroesophageal reflux disorder, smoking habits, exposure to toxic or chemicals fumes and any respiratory problems.

Instrumentation

Computerized Speech Lab (CSL model 4150) designed by Pentax medicals, (Lincoln Park, NJ, USA) tool has its application in the acoustic analysis of voice samples, aiding in the assessment and management of vocal. This tool was used to measure the spectral amplitude measures.

Procedure

For the recording of the voice sample, all the participants were seated on a chair in a quiet room. The voice samples were recorded using a dynamic sensitive microphone, which was kept at a distance of 10 cm from the participant's mouth. All the participants were instructed to phonate and sustain the vowel /a/ at their habitual loudness and pitch and they were instructed to avoid singing it. A demonstration was given on how to carry out the task. In the same way, the participants were instructed to phonate two more vowels, i.e. /i/ and /u/. Each vowel was recorded for three trials.

ANALYSIS

Data Analysis

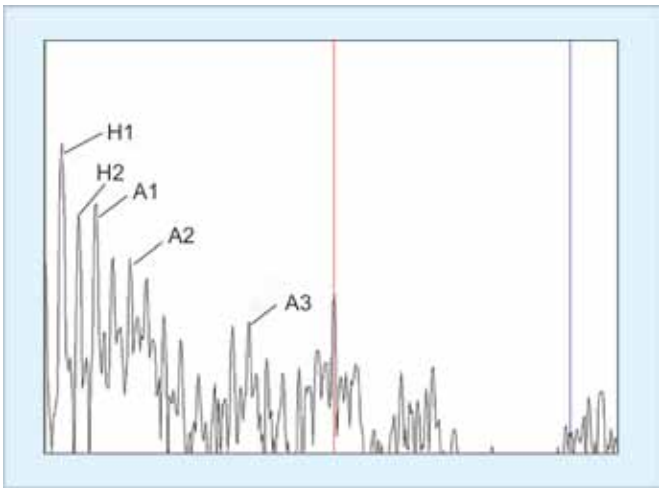
The voice samples were subjected to Fourier transformation to obtain a spectrum. A frame length of two pitch periods representing duration of 40 to 50 msec was selected such that the harmonic ripple could be visualized clearly on the spectrum. The data were sampled at the rate of 22 kHz with FFT set at 2048 points. This converted the voice signal from a time domain signal to the frequency domain signal. The intensity of each of the frequency in the signal was now apparent in the spectrum. The amplitudes of the first two harmonics (H1 and H2 respectively) and the first (A1), second (A2) and the third (A3) formants were measured. A comparison of the amplitudes was made between H1 and all the other amplitudes (H2, A1, A2 and A3 respectively) to obtain the spectral amplitude differences (Graph 1).

Statistical Analysis

All the statistical analysis was done using SPSS version 16.0. Mean and standard deviation were calculated for the spectral amplitude measures to obtain a normative data for all the groups. Further, spectral measures were subjected to two-way analysis of variance (ANOVA), followed by Bonferroni t-test to see significant difference if any across the group and gender.

RESULTS

The present study aimed at estimating the changes in spectral amplitude differences between the first harmonics with the second harmonic (H1-H2) and with the first



Graph 1: Spectrum of the voice sample

three formants (H1-A1, H1-A2 and H1-A3 respectively) of voice in adults. The results are presented under the following sections.

The descriptive statistics were obtained for the spectral amplitude measures across the three groups and gender. The mean and standard deviation scores of spectral amplitude differences across the three groups for each of the respective vowels (/a/, /i/ & /u/) have been depicted in Tables 1 to 3.

As shown in Table 1, group 1 had the largest amplitude differences for all the spectral amplitude measures for the vowel /a/. Among groups 2 and 3, larger amplitude difference was seen for group 2 for the measures H1-A1, H1-A2 and H1-A3, whereas group 3 had a larger amplitude difference than group 2 for the measure H1-H2. And the females had larger amplitude differences than males across all the three groups.

As indicated in Table 2, group 1 had the largest amplitude differences for all the spectral amplitude measures for the vowel /i/. Among groups 2 and 3, larger amplitude difference was seen for group 3 for the measures H1-H2 and H1-A2, whereas group 2 had a larger amplitude difference than group 3 for the measure H1-A1 and H1-A3. Across gender, the females across all the three groups had larger amplitude differences than the males for the spectral amplitude measures.

In Table 3, it is shown that group 1 had the largest amplitude differences for all the spectral amplitude measures for the vowel /u/. Among groups 2 and 3, larger amplitude difference was seen for group 2 for the

Table 1: Descriptive statistics for spectral amplitude measures for the vowel /a/ across the groups and gender

		H1-H2 (dB)		*H1-A1 (dB)*		*H1-A2 (dB)*		*H1-A3 (dB)*	
Vowel /a/	*Gender*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group 1	Males	5.83	5.07	8.22	6.23	15.76	7.64	32.52	7.92
	Females	9.9	2.65	11.41	5.88	17.27	6.45	32.96	6.14
Group 2	Males	3.98	3.23	11.87	4.53	16.5	5.65	32.68	3.71
	Females	7.99	8.06	7.22	10.69	12.67	12.15	27.73	11.33
Group 3	Males	7.6	3.27	7.9	6.56	12.59	6.24	25.59	5.93
	Females	5.17	2.03	7.21	7.03	13.89	6.24	22.47	7.86

SD: Standard deviation

Table 2: Descriptive statistics for spectral amplitude measures for the vowel /i/ across the groups and gender

		H1-H2 (dB)		*H1-A1 (dB)*		*H1-A2 (dB)*		*H1-A3 (dB)*	
Vowel /a/	*Gender*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group 1	Males	3.67	8.66	16.10	10.94	31.73	11.38	29.29	7.62
	Females	13.60	7.59	28.28	9.25	30.69	8.19	33.98	4.76
Group 2	Males	0.41	3.98	10.57	5.92	21.00	6.88	23.52	4.85
	Females	9.32	5.00	27.93	4.53	26.32	8.99	27.47	6.45
Group 3	Males	0.92	4.87	8.34	6.16	21.25	7.42	22.63	6.34
	Females	9.91	6.01	25.48	4.41	26.45	5.29	29.35	6.70

SD: Standard deviation

Table 3: Descriptive statistics for spectral amplitude measures for the vowel /u/ across the groups and gender

		H1-H2 (dB)		*H1-A1 (dB)*		*H1-A2 (dB)*		*H1-A3 (dB)*	
Vowel /a/	*Gender*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Group 1	Males	3.15	7.42	8.68	10.77	19.65	5.94	38.98	8.09
	Females	9.81	7.98	17.18	10.21	27.77	7.56	48.02	3.74
Group 2	Males	1.08	4.28	4.38	6.50	15.54	7.29	34.18	5.26
	Females	7.93	13.51	14.84	10.37	21.81	4.64	38.92	7.15
Group 3	Males	0.16	5.36	2.25	6.41	10.63	6.99	34.94	10.16
	Females	4.85	5.79	15.33	6.75	23.12	9.87	40.69	6.50

SD: Standard deviation

measures H1-H2, H1-A1 and H1-A2, whereas group 3 had a larger amplitude difference than group 2 for the measure H1-A3. And the females had larger spectral amplitude differences than males across all the three groups.

The results of two-way ANOVA have revealed that there was a significant main effect ($p < 0.05$) seen across the groups. For the vowel /a/, the H1-A3 [$t(df = 2) = 14.16$, $p = 0.000$] showed a statistical significant difference among the three groups. The vowel /i/ showed a statistical significant difference among the three groups for all the parameters [H1-H2 {$t(df = 2) = 4.27$, $p = 0.016$}, H1-A1 {$t(df = 2) = 5.27$, $p = 0.006$}, H1-A2 {$t(df = 2) = 10.89$, $p = 0.000$}, H1-A3 {$t(df = 2) = 12.07$, $p = 0.000$}]. And the vowel /u/ showed statistical significant difference for the measures H1-A2 [$t(df = 2) = 9.60$, $p = 0.000$], H1-A3 [$t(df = 2) = 10.15$, $p = 0.000$].

A significant difference was also noted for gender in all the measured parameters for the vowels /i/ [H1-H2 {$t(df = 1) = 66.34$, $p = 0.000$}, H1-A1 {$t(df = 1) = 136.77$, $p = 0.000$}, H1-A2 {$t(df = 1) = 4.39$, $p = 0.038$}, H1-A3 {$t(df = 1) = 20.43$, $p = 0.000$}], and /u/ [H1-H2 {$t(df = 1) = 17.33$, $p = 0.000$}, H1-A1 {$t(df = 1) = 44.92$, $p = 0.000$}, H1-A2 {$t(df = 1) = 46.05$, $p = 0.000$}, H1-A3 {$t(df = 1) = 23.50$, $p = 0.000$}]. And for the vowel /a/, H1-H2 {$t(df = 1) = 5.22$, $p = 0.024$} scores showed a significant difference across the gender.

The Bonferroni post hoc analysis was done to compare the parameters between the groups for all the three vowels. The results of the post hoc analysis for the spectral amplitude measures for each of the respective vowels are shown in Tables 4 to 6.

As shown in Table 4, significant difference in spectral amplitude measures of the vowel /a/ was noted for group 3 when compared with groups 1 and 2 for H1-A3 measure only.

Table 4: Results of post hoc analysis of spectral amplitude measures for the vowel /a/ across the three groups

Vowel /a/	*Groups comparison*		*Mean difference*	*Standard error*	*p-value*
H1-H2	Group 1	Group 2	1.88	1.01	0.19
	Group 1	Group 3	1.47	1.01	0.44
	Group 2	Group 3	– 0.40	1.01	1
H1-A1	Group 1	Group 2	0.02	1.58	1
	Group 1	Group 3	2.26	1.58	0.46
	Group 2	Group 3	2.23	1.58	0.48
H1-A2	Group 1	Group 2	1.92	1.72	0.80
	Group 1	Group 3	3.27	1.72	0.18
	Group 2	Group 3	1.34	1.72	1
H1-A3	Group 1	Group 2	2.53	1.68	0.40
	Group 1	Group 3	8.70*	1.68	0.00
	Group 2	Group 3	6.17*	1.68	0.00

*Indicates significant difference ($p < 0.05$) observed between two groups

Table 5: Results of post hoc analysis of spectral amplitude measures for the vowel /i/ across the three groups

Vowel /i/	*Groups comparison*		*Mean difference*	*Standard error*	*p-value*
H1-H2	Group 1	Group 2	3.77*	1.39	0.02
	Group 1	Group 3	3.22	1.39	0.06
	Group 2	Group 3	– 0.55	1.39	1
H1-A1	Group 1	Group 2	2.93	1.62	0.22
	Group 1	Group 3	5.28*	1.62	0.00
	Group 2	Group 3	2.34	1.62	0.45
H1-A2	Group 1	Group 2	7.55*	1.84	0.00
	Group 1	Group 3	7.35*	1.84	0.00
	Group 2	Group 3	– 0.19	1.84	1
H1-A3	Group 1	Group 2	6.14*	1.38	0.00
	Group 1	Group 3	5.64*	1.38	0.00
	Group 2	Group 3	– 0.49	1.38	1

*Indicates significant difference ($p < 0.05$) observed between two groups

Table 6: Results of post hoc analysis of spectral amplitude measures for the vowel /u/ across the three groups

Vowel /u/	*Groups comparison*		*Mean difference*	*Standard error*	*p-value*
H1-H2	Group 1	Group 2	1.97	1.78	0.81
	Group 1	Group 3	3.98	1.78	0.08
	Group 2	Group 3	2.00	1.78	0.79
H1-A1	Group 1	Group 2	3.31	1.95	0.27
	Group 1	Group 3	4.13	1.95	0.10
	Group 2	Group 3	0.81	1.95	1
H1-A2	Group 1	Group 2	5.03*	1.61	0.00
	Group 1	Group 3	6.83*	1.61	0.00
	Group 2	Group 3	1.79	1.61	0.80
H1-A3	Group 1	Group 2	6.63*	1.59	0.00
	Group 1	Group 3	5.68*	1.59	0.00
	Group 2	Group 3	– 0.95	1.59	1

*Indicates significant difference ($p < 0.05$) observed between two groups

As indicated in Table 5, a significant difference for the vowel /i/ was observed between groups 1 and 2 for all the spectral amplitude measures except H1-A1. And a significant difference was also noted between groups 1 and 3 for all the spectral amplitude measures except H1-H2. No significant difference was observed between groups 2 and 3 for all the spectral amplitude measures.

As depicted in Table 6, there is a significant difference observed for group 1 when compared with groups 2 and 3 for H1-A2 and H1-A3 for the vowel /u/.

DISCUSSION

The anatomical and the physiological changes in the phonatory system with age have an impact on the acoustic properties of an individual's voice. The present study was set to examine the harmonic characteristics of voice in healthy aged individuals in comparison to the young adults and middle-aged adults.

The results of spectral amplitude measure across the age groups have revealed a significant effect of groups, suggesting that as age increases the spectral amplitude differences tend to decrease. This finding was apparent in both the genders. The smaller amplitude differences in the spectral measures of older adults would suggest a pressed phonation in comparison to that of the middle-aged adults and young-aged adults. This could be due to the kind of authoritative and projective voice that the individuals would have developed over the years. This finding could also be attributed to the fact that only normal individuals were recruited in the present study and it was ensured that none of them had any voice problems, history of vocal abuse or misuse, gastroesophageal reflux symptoms, smoking habits, exposure to toxic or chemical fumes and any respiratory problems.

The H1-H2 amplitude difference is the measure of open quotient. It is the difference between the amplitudes of first two harmonics of the vowel spectrum. It tells about the ratio of the open phase in the glottal cycle with that of the total period.[13,14] In the present study, the younger adults have obtained the largest amplitude difference of around 7.5 dB followed by the middle aged with 5 dB and older adults having 4.5 dB. This finding indicates that older adults have pressed voice quality, i.e. smaller open quotient and reduced loss of noise energy in comparison to that of other groups.[5,6]

The H1-A1 is the amplitude differences of the first harmonic (H1) from the first formant frequency (A1). This measure is helpful in predicting the bandwidth of the first formant frequency. The posterior glottal opening and its size is said to have an effect on the first formant bandwidth.[13,14] In the present study, it is evident that the younger adults had higher amplitude difference (14.97 dB), followed by middle-aged adults (12.88 dB) and older adults (11.08) respectively. The findings would again correlate with the H1-H2 findings and suggest that older adults have decreased posterior glottal opening in comparison to the other two groups.[5,6]

The spectral tilt or the airflow though the glottis is said to increase due to factors like the speed of the closure, the presence and the size of the posterior glottal opening and the asymmetric closure of the vocal folds.[13,14] The increase in this spectral tilt of the voice spectra is much evident in the mid and high frequencies, thus the amplitude difference (H1-A2) between the first harmonic (H1) and the second formant frequency (A2) is taken as the measure of spectral tilt at mid frequency. The results of the present study suggest that young-aged adults had highest amplitude differences (23.81 dB) followed by the middle-aged adults (18.97 dB) and older adults (17.99 dB) respectively. This again suggests that with advancements in age, spectral tilt decreases indicating the pressed voice feature in older adults.

Similarly, the amplitude difference (H1-A3) between the first harmonic (H1) and the third formant frequency (A3) is a measure that tells about the spectral tilt at higher frequency region.[13,14] In the present study, H1-A3 was observed to be decreasing with age, whereas young-aged adults had obtained highest amplitude differences (35.95 dB) followed by the middle-aged adults (30.85 dB) and older adults (29.28 dB) respectively. Thus, older adults are having lesser energy loss of the glottal source at the higher frequency.

The comparison across the gender indicated a significant effect for all the measured parameters for the vowels /i/ and /u/ and in H1-H2 for the vowel /a/. The spectral measures showed smaller spectral amplitude differences in males when compared with females, suggesting a better quality of voice in males when compared with females. The fibroscopic studies have shown that males have a much complete closure of the glottal area compared with females, which in turn lead to lesser loss of energy at the glottis and lesser spectral tilt.[15] The gender difference in the present study could be because of larger open quotient[16] and larger relative amplitude of the first harmonics[17] seen in females due to the presence of posterior chink.[18] The presence of posterior chink has been reported to be associated with high frequency spectral noise.[19] This in turn would decrease the harmonic organization of voice in females. And the hormone-related factors like premenstrual dysphonia, pregnancy, menopause, consumption of contraceptive pill and hormone replacement therapy would also have an effect on the quality of voice of females.[20]

The reason for the nonsignificant differences in the parameters measured for vowel /a/ when compared with vowel /i/ and /u/ could be due to the low first formants of /i/ and /u/ which might artificially amplify the first or second harmonics yielding a greater spectral difference compared to the vowel /a/.[15]

After the age of 65 years, the voice is said to decline in much the same way like the other body functions.[9,21] However, the voice does not always reflect the changes that might occur in the physical functioning of the body. There is no particular characteristic that would define every voice that is aging. The anatomical or the physiological changes due to aging could vary from person to person. Few individuals will have a well-preserved voice even at their 80's, whereas few others' voices begin to decline from their 50's. There are studies which have reported the aged individuals having good physical condition have the quality of voice which is similar to that of the younger individuals.[22] There are also evidences

that the singers could maintain their voices till their 7th decade. The voice quality degradation is said to depend on various factors like the food habits, lifestyle, alcohol consumption, smoking habits and so on.[9,23] Genetics is also one of the important factors which could influence the age-related changes in voice. All these factors would have played a role in the voice of the older adults in comparison to middle and younger adults.

CONCLUSION

The aim of the present study was to estimate the spectral amplitude measures for healthy aging population. Results revealed that the older adults had smaller amplitude differences, followed by middle-aged adults and young-aged adults respectively. Gender differences showed that females had larger spectral amplitude differences when compared with males. Vowels /i/ and /u/ could significantly discriminate the age and gender differences in comparison to vowel /a/. During the voice recording, the loudness of the voice was not controlled; this would have led to the better values in the measured parameters. The age range of group 3 participants were between 61 and 75 years. Thus, the age-related decline in the voice during the 8th and 9th decade of life is not accounted for, in the study.

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