

Acoustic Analysis of Normal Voice Patterns in Pakistani Adults

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Summary: This study was designed to find out normative acoustic measures of adults in Pakistan. Age and gender differences in these parameters were also studied. The study variables include fundamental frequency, absolute jitter, relative jitter, relative average perturbation, 5-point period perturbation quotient perturbation quotient, jitter average absolute difference between consecutive periods, divided by the average period, shimmer local, shimmer decibel, three-point amplitude perturbation quotient, five-point amplitude perturbation quotient, average absolute difference of consecutive differences between the consecutive periods' amplitudes, and harmonics-to-noise ratio. Participants (N = 71; men = 34; women = 37) were recruited through two-stage sampling; convenience and purposive sampling. Participants were selected from students, staff, and faculty of the University of the Punjab, caretakers of the clients coming for clinical services, and researchers' friends, family, and acquaintances. Gender groups were further divided into three sub-groups based on the age bands of 21–30, 31–40, and 41–50 years. After screening for health issues, the voice samples were recorded in a sound-proof acoustic laboratory by using a stand-held microphone and *Praat* software. Praat was also used for voice analyses. Means and standard deviations were conducted for the participants. Age and gender differences were investigated by using the two-way analysis of variance. Normative values were also measured for men and women between the age bracket of 21 and 50 years. Age differences were not significant for any variable. Gender differences were significant in fundamental frequency, absolute jitter, relative jitter, jitter period perturbation quotient, shimmer five-point amplitude perturbation quotient, and harmonics-to-noise ratio. The interaction between age and gender was significant in all the jitter measures. The interaction showed an increase in all these measures between the ages of 31 and 40 years and a decrease between the ages of 41 and 50 years in women, whereas men showed a reverse effect both in the age ranges of 31–40 and 41–50 years.

Key Words: Acoustics–F₀–Jitter–Shimmer–Harmonics-to-noise ratio (HNR).

INTRODUCTION

Acoustic analysis has become more widely used and preferable because of the enhanced usage of personal computers in the clinical settings. Many software have been developed for this purpose, namely, *Praat*,¹ *Dr. Speech*,² and *Multidimensional Voice Program*³ etc. Acoustic voice analysis is considered to be a very valuable technique for the detection of pathology^{4,5} as voice disorders can be detected by analyzing several acoustic parameters.⁶ Subjective assessment methods, such as auditory perceptual analysis, are used widely by professionals in this field. These methods depend largely on the experience of the professionals, and may lead to different results because of lack of agreement among them. This requirement encourages the use of objective measurement of the voice. Processing of a speech signal is used to yield a set of voice parameters. It allows the detection of vocal fold pathologies, or other related pathologies in individuals, by comparing patients' data with that of other individuals having normal healthy voices.⁶

Voice disorders, resulting from neurologic, structural, functional, and psychogenic pathologies, require voice therapy and other related treatments. These are based on an initial assessment to quantify the deviation from normal measures and an ongoing evaluation to keep record of the progress. Measuring

the treatment outcomes is the basic component of the evidence-based practice. The objective assessment of voice, especially the acoustic analysis, has received considerable attention, because of its comparatively low cost, ease of application, and quantitative output. These features encouraged researchers and clinicians to standardize the main parameters, to get comparable figures with record deviation, and progress in the voice patterns. The normative data obtained from these studies help the clinicians in assessment and management of voice disorders. In Pakistan, research in this field is still in its early stages, and no study had been found to standardize the acoustic parameters for *Praat*.¹ Hence, along with fulfilling these important clinical needs, the present work was planned to fill some crucial gaps in the relevant literature.

Previous studies^{7,8} have found that fundamental frequency (F₀) can be affected by different factors, that is, age, vocal fold length, and language or ethnological background. It was also observed that the most commonly used acoustic parameters depend on F₀. This fact emphasizes the need to establish normative data for each computerized acoustic analysis program in different language or ethnological background separately. Research has been conducted in this regard, in different countries.^{9–12} According to the researchers' knowledge, no such research has been conducted in Pakistan to date. Standardization of the acoustic data has significant implications for voice clinicians, students of speech and language pathology, and manufacturers of the instrumentation. Acoustic analyses of voice samples provide important information regarding one's vocal health. Whenever a patient's voice sample is examined, normative acoustic parameters are required to compare it with healthy voices.

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The mean values of acoustic parameters suggested by Williamson¹³ were being used as normative data in Pakistan before this study. The current study was designed to standardize these measures for Pakistani population by using *Praat*. Acoustic parameters to be studied included F_0 , absolute jitter, relative jitter, relative average perturbation (RAP), period perturbation quotient (PPQ5), jitter average absolute difference between consecutive periods, divided by the average period (DDP), shimmer local, shimmer decibel (dB), three-point amplitude perturbation quotient (APQ3), five-point amplitude perturbation quotient (APQ5), average absolute difference of consecutive differences between the consecutive periods' amplitudes (DDA), and harmonics-to-noise ratio (HNR). This study was aimed to obtain the normative acoustic measures in Pakistani adults and to find out age and gender differences in the acoustic parameters of normal voices.

The parameters

Fundamental frequency (F_0)

It is very important and main acoustic parameter in the voice assessment. It helps both in the functional and in the anatomic laryngeal assessment and is computed by the total number of cycles per second, by the vocal folds.¹⁴ According to Carson et al,¹⁵ F_0 has been proved to be the most consistent of all acoustic parameters.

Perturbation analysis

Perturbation analysis is based on the evidence that in a voice signal, small variations in frequency, amplitude, and waveform are always present, reflecting the internal noises of the human body.¹⁶ To describe the vocal characteristics, the measurements of these perturbations, or fluctuations in F_0 , that is, shimmer and jitter have been found to be very useful. Jitter is the measure of cycle-to-cycle variation in F_0 of voice,^{17,18} whereas shimmer is the measure of cycle-to-cycle variation in amplitude.¹⁹

As it is mentioned before that jitter and shimmer provide important information regarding voice signal and vocal health, and the lack of control over vocal fold vibrations is reported to have an effect on jitter. The higher percentage of jitter is noted in the voices of patients with vocal fold pathologies.⁶ Shimmer is found to be changed with the reduction in glottal resistance and with the vocal fold lesions. It is also linked with the incidence of the breathiness and emission of noise. Vocal quality changes because of the laryngeal diseases. Deterioration of voice is normally executed by the hoarseness and breathiness of voice.⁶ This fact emphasizes the importance of jitter and shimmer as a parameter to indicate and evaluate a laryngeal malfunction at an early stage.

Jitter. The measurement of jitter can be done by the following parameters: absolute jitter, local or relative jitter, RAP, and the five-point period perturbation quotient (PPQ5).²⁰⁻²³

- (1) *Jitter absolute or local.* This is the cycle-to-cycle variation in the F_0 .

- (2) *Relative or local jitter.* This is "the average absolute difference between consecutive periods, divided by average period, expressed as a percentage."²²
- (3) *Jitter (RAP).* This is relative average perturbation, calculated as "the average absolute difference between a period and the average of it and its two neighbors, divided by the average period. It is expressed as a percentage."²²
- (4) *Jitter (PPQ5).* This is "the five-point period perturbation quotient, computed as the average absolute difference between a period and the average of it and its four closest neighbors, divided by the average period."²² It is also expressed as a percentage.
- (5) *Jitter (DDP).* This is "the average absolute difference between consecutive periods, divided by the average period."²² Its value is three times RAP.

Shimmer. Shimmer measurements are typically performed only on long-sustained vowels. These can be measured as follows:

- (1) *Shimmer (local).* This is "the average absolute difference between the amplitudes of the consecutive periods, divided by the average amplitude. It is expressed as a percentage."²²
- (2) *Shimmer (dB).* It is expressed as the changeability of the amplitude from peak-to-peak. The unit of shimmer is dB.
- (3) *Shimmer (APQ3).* This is "the three-point amplitude perturbation quotient, the average absolute difference between the amplitude of a period and the average of amplitudes of its neighbors, divided by the average amplitude. It is expressed in percentage."²²
- (4) *Shimmer (APQ5).* This is defined as "the five-point amplitude perturbation quotient, the average absolute difference between the amplitude of a period and the average of the amplitudes of its four closest neighbors, divided by the average amplitude. It is also expressed in percentage."²²
- (5) *Shimmer (DDA).* This is "the average absolute difference between consecutive differences, between the amplitudes of the consecutive periods."²² It is three times the value of APQ3.

Harmonics-to-noise ratio (HNR). It can be computed for only a periodic signal, that is, a sustained vowel. It indicates the general periodicity of the signal of voice, by calculating the proportion between the periodic and the aperiodic elements. Instead of being measured as a function of frequency, it is generally measured as a general signal characteristic. The overall HNR value of the signal fluctuates, as various vocal tract formations present diverse amplitudes for the harmonics.²⁴⁻²⁷

Maximum phonation time. The ability of easily bringing the vocal folds together throughout their length is very important for the good vocal quality. The glottis is the space between vocal folds, and it is needed to be closed with appropriate amount of tension. The vibrations of vocal folds occur about 100 and 200 times per second for adult males and females,

respectively, during the phonation of voiced speech sound.¹³ The ability of closing (adduct) the vocal folds efficiently is important both for normal and for healthy phonation as well as for protecting the air passage from foreign particles. It is also necessary for the closure needed for a strong cough.¹³ This whole function is referred as glottal efficiency. Because of the ease of application and simplicity, maximum phonation time is frequently used as a clinical tool to test the glottal efficiency. The longest duration, an individual can sustain, of a vowel sound (typically /a:/) is called maximum phonation time.²⁸ This task is performed at a somewhat comfortable pitch and loudness, and the total duration is documented in seconds.¹³

HYPOTHESES

- Acoustic voice parameters are different in the two genders across different age groups (21–30, 31–40, and 41–50 years).
- Acoustic voice parameters are different for men and women.

METHOD

Target population for this study comprised both men and women, with minimum age of 21 years as voice alterations occur normally during puberty.²⁹ Maximum age was 50 years because voice is also modified because of the aging of vocal mechanism.³⁰ Seventy-one participants were included in this study. The sample size was projected through power analysis using G-power³¹ computer program, with a large effect size ($\alpha = .05$; $\beta = .95$) estimated from the previous F_0 findings.¹¹ Total sample size was suggested to be 72, with 12 participants in each group ($N = 6$).

Two-stage sampling involving convenient and purposive techniques was used. First, participants were approached through convenience sampling. Then, screening was carried out for the participants who agreed to volunteer for this study. The men and women, who met the selection criteria, were recruited. Total 34 men and 37 women were recruited from the students, staff, and faculty of the University of the Punjab, caretakers or family members of the clients coming for clinical services, and the researchers' friends, family, and acquaintances. Three subgroups on the basis of the following age brackets were made, that is, 20–30 years, 31–40 years, and 41–50 years.

The following criteria were used for the selection of the participants in this research work.

Inclusion criteria

Inclusion criterion set for the participants imposed the following restrictions.

1. A nonsmoker or left smoking at least 5 years ago
2. To be able to phonate and sustain a vowel for at least 10 seconds
3. Able to understand and speak Urdu

Exclusion criteria

The participants were excluded if they met any of the following criteria.

1. Having a hoarse voice on the day of recording, assessed through perceptual voice assessment by using the grade, roughness, breathiness, asthenia, strain scale.
2. The participant reported recent voice problems or a voice disorder history.
3. The participant took medication, or had a condition that might affect the normal voice function.
4. The participant had any laryngeal, mouth, or throat abnormality.
5. The participant had any respiratory mechanism infection for the last 3 weeks before recording.
6. The participant had any previous formal voice training or voice therapy.

Instruments

Screening measures

Inclusion and exclusion sheet. An inclusion and exclusion sheet was constructed to collect information regarding the participants' age, gender, languages spoken and the understanding of Urdu language, and any previous voice therapy or training.

Health-related questionnaire for participants. It was developed by Goy et al⁹ for screening purpose in their study. Their study was titled as "Normative Voice Data for Younger and Older Adults."

Grade, roughness, breathiness, asthenia, strain scale. This scale is the most commonly used tool for perceptual assessment of a voice. It was developed by Hirano³² and comprises five qualitative characteristics including grade of dysphonia (G), roughness (R), breathiness (B), asthenia (A), and strain (S). A value between the ranges of 0 and 3 is marked for each characteristic, where a zero corresponds to a normal healthy voice, 1 to mild, 2 to moderate, and 3 to a severe one.

Assessment of study variables

Praat

"*Praat*" is a Dutch word that means "talk" or "speak." It is a computer software package available free of cost for speech, phonetic, and voice analyses. It was first designed in 1992 by Paul Boersma and David Weenick from the Institute of Phonetic Sciences, University of Amsterdam, and they further continued to develop this computational platform. Currently, it is updated to version 6.0.22.¹ *Praat* can be used on various operating systems and uses the finest algorithms including the most accurate algorithm of pitch analysis, the articulatory synthesis, and the gradual learning algorithm for free variation.³³ The current study used *Praat* for voice analyses for which the software employs "peak-picking algorithm or cross-correlation." It has an inbuilt option of voice report in its pulses menu, which includes pitch and perturbation analyses. To take benefit from the most accurate

analyses, the pitch settings are required to be optimized for voice analyses.

Procedure

Approval from the Departmental Doctoral Program Committee, Centre for Clinical Psychology, University of the Punjab, Lahore, Pakistan was sought for conducting this research. Original authors and developers were contacted to take permissions for using the proposed scales and software for data collection and analyses. The administrations of different departments in the University of the Punjab were also contacted to obtain permission for data collection.

The participants were approached, informed about the study objectives and significance, and were asked about their willingness to participate in the present research. If they volunteered to participate, screening was carried out through the inclusion and exclusion sheet, health-related questionnaire,⁹ and grade, roughness, breathiness, asthenia, strain scale.³² Only the individuals fulfilling the selection criteria (see Inclusion criteria and Exclusion criteria sections) were recruited.

The selected participants were asked to give their consent to participate in the study and were requested to come to the acoustic laboratory situated at the Centre for Clinical Psychology, University of the Punjab, for voice recording. It is a sound-treated laboratory, with minimal environmental noise.

Elicitation of voice sample

The elicitation of all required trials for a voice sample took a maximum time of 10 minutes for each participant. The participants were asked to stand in front of the microphone, which was held on a stand. PL-24 entry-level dynamic vocal microphone was used for this purpose. The microphone was connected to a Dell Inspiron laptop (Dell Inc., USA), whereas the voice samples were recorded directly in *Praat*¹ at a frequency of 8000 Hz by keeping in view the specifications of the microphone.

Each participant was instructed to maintain a distance of 1.5 inches between his or her mouth and the microphone. A scale was attached to the microphone to maintain the distance. The voice samples were recorded for the F_0 and perturbation measures, by using a sustained vowel /a:/ at least for 6 seconds as the objective measures, that is, jitter, shimmer, HNR are typically analyzed on long-sustained vowels.⁶ The participants were asked to perform test trials of phonation before recording, at habitual vocal loudness and pitch. At least three final trials were recorded for each participant. If a sample was not recorded appropriately, more trials were carried out until three valid recordings were collected.

Voice Analyses

These voice samples were acoustically analyzed by using *Praat*¹ to find objective voice measurements including the F_0 , jitter, shimmer, and HNR.

The voice samples collected for perturbation measures were analyzed by selecting the middle 3 seconds from the sound wave with the initial 0.5 seconds, and the ending of voice signal was discarded. The objective was to avoid irregular patterns observed at the starting and ending of voice signal. The selected

sound wave was extracted in a new window, and the inbuilt system in *Praat*¹ was used to obtain the measures. The procedure was done for each trial of each individual participant. After analyzing all the three trials recorded by a participant, averages of the obtained measures were also calculated.

RESULTS

Data analyses were conducted through *SPSS Statistics* v21 (IBM Corporation, USA). [Table 1](#) presents the descriptive statistics for all participants. The normative values of all acoustic parameters for both genders across the age ranges of 21–30, 31–40 and 41–50 years are presented in [Table 2](#). The data distribution was found to be within one standard deviation, for each parameter ([Table 2](#)).

Two-way analyses of variance were used for finding the age and gender differences in all the acoustic parameters with three levels of age (21–30 years, 31–40 years, and 41–50 years), and two levels of gender (men and women). [Tables 3–10](#) present the findings of two-way analysis of variance.

There were no age differences in the mean values of F_0 , whereas significant gender difference was found in these values, showing that the women had significantly higher means for F_0 than in those of men. The interaction of age and gender was found to be nonsignificant.

No significant age differences were observed in these values. There were significant gender differences, which revealed considerably higher means for men for absolute jitter as compared with those of women. The interaction between age and gender was also found to be statistically significant. The plot in [Figure 1](#) showed that the mean values for absolute jitter decreased in men between the ages of 31 and 40 years, and then increased in the ages of 41 and 50 years, whereas the women showed an increase in their corresponding values for this parameter between the ages of 31 and 40 years, and then a marked decrease in 41 and 50 years.

The age differences were found to be nonsignificant, although statistically significant gender differences were noticed in the relative jitter. It reveals that men had higher relative jitter than do women. Age and gender also showed significant interaction on relative jitter. [Figure 2](#) showed a significant decrease in relative jitter in men between the age brackets of 31 and 40 years, and a further noteworthy increase in the age group of 41–50 years. In the women, relative jitter first significantly increased

TABLE 1.
Descriptive Statistics of Participants' Age and Gender

	N	M	SD
Men (age, y)			
21–30	10	25.00	3.20
31–40	14	35.36	2.17
41–50	10	45.40	3.44
Women (age, y)			
21–30	17	25.65	1.77
31–40	10	33.80	3.01
41–50	10	44.10	3.18

TABLE 2.
Normative Acoustic Parameters Presented on the Bases of Age and Gender

Acoustic Parameters (Units)	Men			Women		
	21–30	31–40	41–50	21–30	31–40	41–50
F0 (Hz)	130.08 ± 21.84	133.84 ± 23.86	128.07 ± 17.22	240.76* ± 34.25	211.03 ± 25.83	213.08 ± 26.69
Absolute jitter (s)	35.68 ± 15.23	25.42 ± 10.11	41.96 ± 18.54	14.11 ± 5.03	20.52 ± 7.26	13.28 ± 5.67
Jitter PPO5 (%)	0.23 ± 0.08	0.17 ± 0.05	0.27 ± 0.11	0.20 ± 0.07	0.25 ± 0.08	0.15 ± 0.07
Jitter DDP (%)	0.26 ± 0.08	0.19 ± 0.06	0.33 ± 0.11	0.18 ± 0.07	0.24 ± 0.08	0.18 ± 0.11
Shimmer local (%)	0.74 ± 0.25	0.51 ± 0.16	0.82 ± 0.33	0.60 ± 0.22	0.75 ± 0.26	0.45 ± 0.20
Shimmer dB (dB)	2.40 ± 0.77	3.10 ± 1.69	4.05 ± 3.09	2.20 ± 1.06	2.86 ± 0.97	2.28 ± 0.61
Shimmer APQ3 (%)	0.21 ± 0.07	0.28 ± 0.15	0.36 ± 0.28	0.25 ± 0.19	0.25 ± 0.09	0.21 ± 0.06
Shimmer APQ5 (%)	1.25 ± 0.45	1.69 ± 1.10	2.03 ± 1.39	1.26 ± 0.65	1.65 ± 0.60	1.22 ± 0.32
Shimmer APQ5 (%)	1.45 ± 0.48	1.82 ± 0.86	2.49 ± 1.96	1.30 ± 0.62	1.68 ± 0.53	1.37 ± 0.37
Shimmer DDA (%)	3.75 ± 1.36	5.02 ± 3.35	6.10 ± 4.418	3.79 ± 1.94	4.96 ± 1.80	3.66 ± 0.95
HNR (dB)	23.39 ± 3.18	23.18 ± 4.16	22.13 ± 4.76	26.47 ± 3.19	24.43 ± 2.25	26.29 ± 2.22

* The mean F0 found for women (21–30 years) is found to be higher (240.76 Hz) than other groups, that is, 31–40 and 41–50 years (211.03 Hz and 213.08 Hz). Two outliers were found in the group of women 21–30 years old with significantly higher F₀ and it was suspected that unusually high mean F₀ for this group might have been because of this outlier. The mean F₀ calculated after excluding them was found to be 231.79 Hz.

Abbreviations: APQ3, three-point amplitude perturbation quotient; APQ5, five-point amplitude perturbation quotient; dB, decibel; DDA, average absolute difference of consecutive differences between the consecutive periods' amplitudes; DDP, average absolute difference between consecutive periods, divided by the average period; F₀, fundamental frequency; HNR, harmonics-to-noise ratio; PPO5, five-point period perturbation quotient; RAP, relative average perturbation.

TABLE 3.
Age and Gender Differences in Fundamental Frequency

Source	df	F	P
Age	2	2.20	0.119
Gender	1	200.39	<0.001
Age × Gender	2	2.65	0.078

TABLE 7.
Age and Gender Differences in Jitter PPO5

Source	df	F	P
Age	2	1.46	0.240
Gender	1	8.51	0.005
Age × Gender	2	8.46	0.001

TABLE 4.
Age and Gender Differences in Absolute Jitter

Source	df	F	P
Age	2	0.99	0.377
Gender	1	48.54	<0.001
Age × Gender	2	6.99	0.002

TABLE 8.
Age and Gender Differences in Jitter DDP

Source	df	F	P
Age	2	0.21	0.813
Gender	1	2.38	0.128
Age × Gender	2	9.53	<0.001

TABLE 5.
Age and Gender Differences in Relative Jitter

Source	df	F	P
Age	2	0.14	0.871
Gender	1	7.37	0.009
Age × Gender	2	10.07	<0.001

TABLE 9.
Age and Gender Differences in Shimmer APQ5

Source	df	F	P
Age	2	2.18	0.121
Gender	1	4.36	0.041
Age × Gender	2	1.93	0.153

TABLE 6.
Age and Gender Differences in Jitter RAP

Source	df	F	P
Age	2	0.15	0.858
Gender	1	2.47	0.121
Age × Gender	2	9.79	<0.001

TABLE 10.
Age and Gender Differences in HNR

Source	df	F	P
Age	2	0.66	0.520
Gender	1	11.47	0.001
Age × Gender	2	0.99	0.376

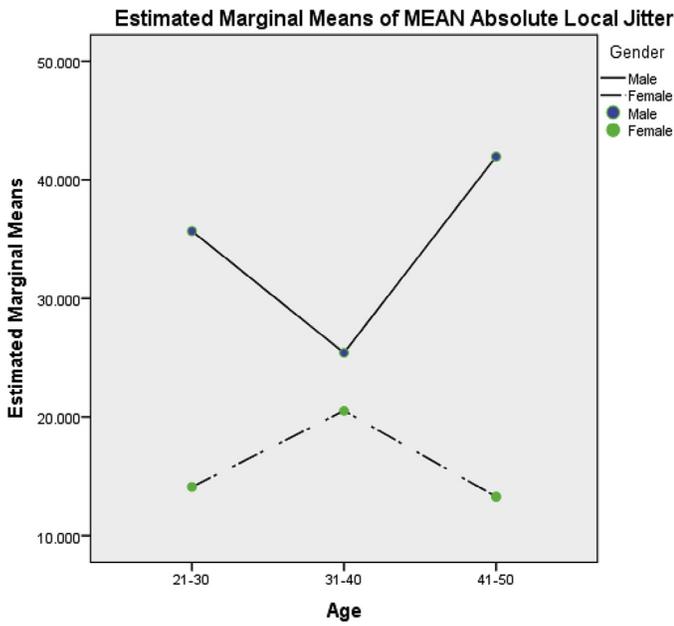


FIGURE 1. Plot showing the interaction between age and gender on absolute jitter.

in the age group of 31–40 years, and then decreased with higher age levels.

Two-way analysis of variance showed no significant age and gender differences in jitter RAP, although there was a significant interaction between age and gender on this measure. The plot in Figure 3 showed marked changes in the jitter RAP over the age group of 21–50 years in both the men and the women. For the male participants, jitter RAP decreased in the ages of 31–40 years, and then increased in 41–50 years, whereas the

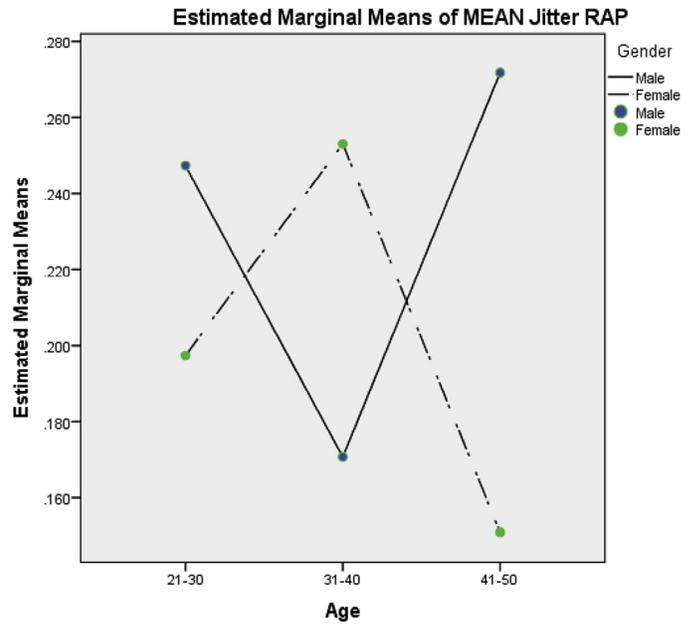


FIGURE 3. Plot showing the interaction between age and gender on jitter RAP.

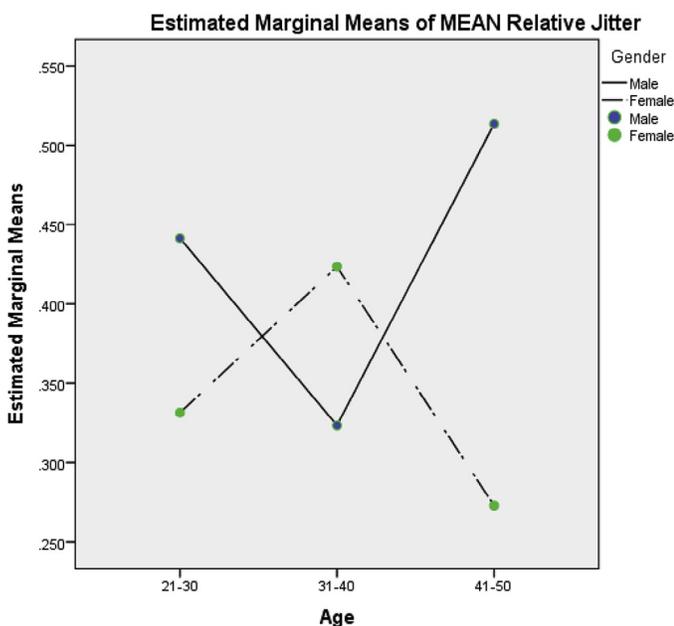


FIGURE 2. Plot showing the interaction between age and gender on relative jitter.

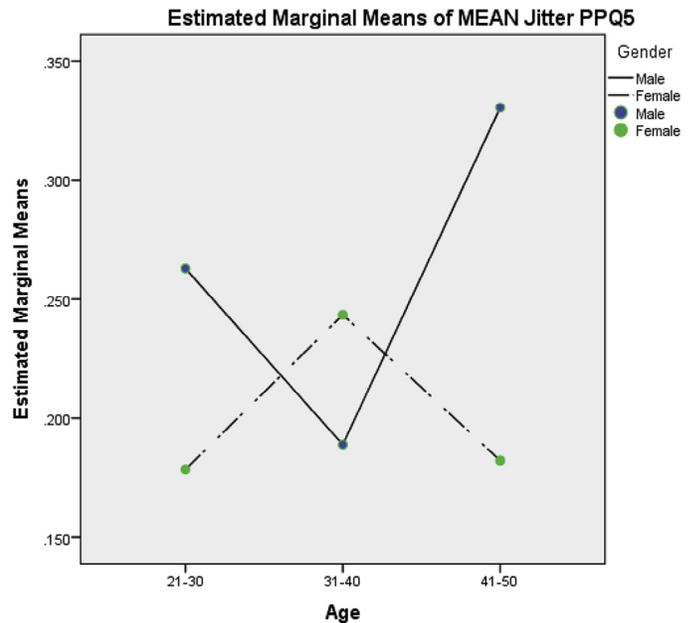


FIGURE 4. Plot showing the interaction between age and gender on jitter PPQ5.

women showed a reverse effect with an increase in these values between the age brackets of 31–40 years, and decrease in 41–50 years.

There were significant differences in jitter PPQ5 on the basis of gender, but not on the age group. It revealed that the means for jitter PPQ5 were higher for the men than in those for the women. Age and gender also showed significant interaction on these values. The plot in Figure 4 suggested a significant decrease in jitter PPQ in the men for the age group of 31–40 years, and then, an increase in further years, that is, 41–50 years. For

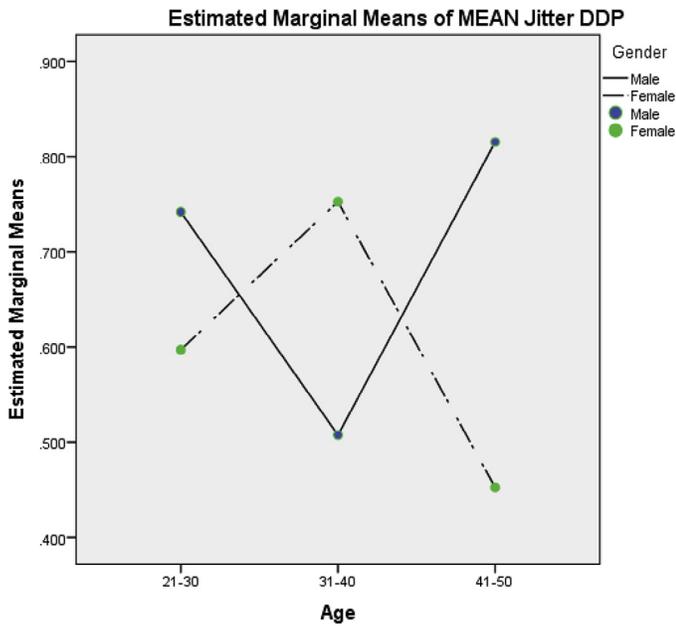


FIGURE 5. Plot showing the interaction between age and gender on jitter DDP.

the female participants, these values were seen to be increased in the age bracket of 31–40 years, and decreased in 41–50 years (Table 8).

There were no significant age and gender differences in jitter DDP, whereas a statistically significant interaction between age and gender was found. Furthermore, the plot in Figure 5 showed this interaction, and revealed a decrease in these values in the men between the age group of 31 and 40 years, and an increase for 41–50 years. The women showed a complete reverse interaction of age and gender on jitter DDP because higher values were noticed in the age groups of 31–40 years, which further decreased for those aged 41–50 years (Table 9).

No age differences were observed in shimmer APQ5, whereas gender differences were noticed to be statistically significant, which revealed that the men had considerably higher shimmer APQ5 than do women. There was no significant interaction between age and gender (Table 10).

There seems to be no age differences in the mean values of HNR. Significant gender differences were found showing higher HNR means in the women than in those of the men. The interaction between age and gender was also nonsignificant.

The results for shimmer local, dB, APQ3, and DDA are not presented as they neither showed significant age and gender differences, nor significant interaction between age and gender.

DISCUSSION

It was hypothesized that there are likely to be age and gender differences in the acoustic parameters of men and women. These hypotheses are partially supported by the current results. In this section, the findings for each parameter are discussed individually.

The F_0 values for the Pakistani men (131.04 Hz) and women (225.24 Hz) are found to be lower than those of the Nepalese

population ($M = 170.05$ Hz; $W = 246.45$ Hz),¹⁰ and higher than those for Taiwanese ($M = 121.3$ Hz; $W = 213.4$ Hz)¹¹ and Iranian population ($M = 112.82$ Hz; $W = 112.82$ Hz).¹² DeJong et al³⁴ studied F_0 of Urdu speakers and reported similar values for F_0 for men (129 Hz) and comparatively lower F_0 for women (205 Hz) in reference to the present F_0 findings. No age differences are found in F_0 of men and women participants, but there are significant gender differences revealed in the results. The women showed higher F_0 than did men. No significant interaction between age and gender could be seen. The studies conducted on Taiwanese¹¹ and Canadian adults⁹ showed similar findings, with no age differences in F_0 of men and women. The gender differences in F_0 can be justified because there are marked anatomic differences in the larynges of men and women. A male larynx appears to be approximately 40% bigger than that of a female, and the male vocal folds consist of a thicker mass.³⁵ Previous research carried out on Nepalese adults aged from 20 to 39 years,¹⁰ Taiwanese adults aged from 20 to 49 years,¹¹ and Iranian adults aged from 21 to 50 years¹² also support these gender differences in F_0 . Similar to the results of the current study, these research also reported the F_0 values to be significantly higher in women than in men.

In most of the previous studies, only relative jitter was reported from pitch perturbation measures. In the current population, these values are found to be higher both in men (0.41%) and in women (0.34%) as compared with the Nepalese ($M = 0.14\%$; $W = 0.14\%$)¹⁰ and the Iranian population ($M = 0.23\%$; $W = 0.22\%$),¹² and lower than the Taiwanese population ($M = 0.56\%$; $W = 0.66\%$).¹¹ In the current study, absolute jitter is not found to be affected by the age, but gender differences and the interaction of age and gender are revealed to be statistically significant. Goy et al⁹ found different results as they reported significant age differences in absolute jitter of younger and older males and females. The disagreement of findings can be justified because the participants in their study included younger participants between the ages of 18 and 28 years and older participants between the ages of 63 and 86 years. The findings of the same study support the current results, revealing a significant gender difference in absolute jitter. In the present study, the age and gender interaction showed that absolute jitter first decreased for males aged 31–40 years, and then increased. Whereas in females, it increased for the age group of 31–40 years, and then decreased for the age bracket of 41–50 years. No previous study reported the interaction between age and gender on absolute jitter.

Age differences in relative jitter are found to be insignificant, whereas significant gender differences and interaction of age and gender are seen on relative jitter. Previous studies by Goy et al⁹ and Wang and Huang¹¹ also reported no age-related differences in men or women. The present study found significant gender differences in relative jitter that does not concur with the previously presented results.^{10,15} Significant interaction of age and gender is also seen on relative jitter, which showed reverse effects in men and women. For the age of 31–40 years, relative jitter was decreased in men and increased in women, with a further rise in men and decline in women between the ages of 41 and 50 years.

In jitter RAP, no statistically significant age or gender differences are found. Goy et al⁹ also found the similar finding regarding age differences. They found the values of jitter RAP to be stable over the age when compared with the values for younger adults (aged 18–28 years) and older adults (aged 63–86 years). The present study reported that age and gender had a significant interaction on jitter RAP, further showing higher values in women between the ages of 31 and 40 years as compared with other age groups (21–30 years and 41–50 years) and lower values in men between the ages of 31 and 40 years as compared with the two other age groups (21–30 years and 41–50 years).

Similar to other jitter measures discussed above and the previous results,⁹ age differences in jitter PPQ5 for both men and women are also insignificant. The gender differences in PPAQ5 and the interaction between age and gender could not be found, coinciding with the previous literature. The current study revealed significant gender differences and interaction between age and gender in jitter PPQ5. In jitter PPQ5, too, the values increased for group of age between 31 and 40 years in women, and decreased in men for the same age bracket. The plot (Figure 4) also showed jitter PPQ5 to be decreasing in women, and increasing in men for the age lying in the bracket of 41–50 years.

No age and gender differences are found in jitter DDP in the present study. It is the first time when jitter DDP was studied in reference to these differences. None of the previous studies reported jitter DDP or age or gender differences in it. The current findings showed significant age and gender interaction (Figure 5) on this measure. It showed similar changes in men and women as reported in all the abovementioned jitter measures. Although, unlike the previous studies,^{9–11} overall current findings related to all the jitter measures have indicated that the women tend to have better control over their voices when they reach the age bracket of 41–50 years as compared with the males. It is because phonatory instability, for example, because of aging, has been linked with increased jitter values.³⁶

One previous study¹¹ has reported only shimmer (dB) from intensity perturbation measures which were lower (0.22 dB) in men and higher (1.83 dB) in women as compared with the Pakistani population (M = 0.28 dB; W = 0.24 dB). Other studies by Dehqan et al¹² and Toran and Lal¹⁰ reported shimmer local and reported lower values in Iranian (M = 1.22%; W = 1.2%) and Nepalese (M = 1.6%; W = 1.6%) populations, respectively. None of the shimmer measures showed significant age differences or a significant age and gender interaction. Moreover, no significant gender differences are found in any of the shimmer measures except shimmer APQ5. Toran and Lal¹⁰ studied the voices of normal young Nepalese adults between the ages of 20 and 39 years to investigate gender differences in them. They studied only shimmer local from all the shimmer measures. They found similar results of comparable shimmer values in both genders. In another study,¹¹ normal voices of Taiwanese men and women aged between 20 and 49 years were investigated. It showed stable shimmer (dB) values in women over these age brackets, which are similar to the present findings. Although unlike the current results, this

previous study reported that these values changed significantly in men over the age bracket of 20–49 years. A study⁹ on the voices of Canadian younger (aged 18–28 years) and older adults (aged 63–86 years) reported results similar to those reported by Wang and Huang¹¹ in their study. The difference in the current and previous findings can be explained on the basis that a different software was used in each study, which might have used different algorithms for the estimation of perturbation measures; *Praat* in the current study, *Computerized Speech Lab* system in the studies by Wang and Huang,¹¹ and *Sonneta* (MintLeaf Software Inc., Toronto, Canada) by Goy et al.⁹ One of the previous studies¹² conducted on Iranian adults with an age range of 21–50 years reported similar findings as presented in the present research. Dehqan et al¹² studied only the shimmer local from all the shimmer measures, and reported no age differences in men and women over the age bracket of 21–50 years. Also, there were no significant gender differences.

HNR values in the present study (M = 22.93 dB; W = 25.87 dB) are found to be similar to the Nepalese population (M = 25.82 dB; W = 25.88 dB),¹⁰ and higher than those reported for Taiwanese (M = 10.1 dB; W = 12.2 dB)¹¹ and Iranian population (M = 18.42 dB; W = 18.81 dB).¹² Goy et al⁹ stated that as compared with those studies, in which voice perturbation was investigated, fewer research efforts explored the HNR or the age and gender differences in the noise exhibited in the human voice signal. HNR was suggested to be an important index of vocal aging by Ferrand³⁰ in her study conducted in three groups of women, that is, the young adults (21–34 years), middle-aged (40–63 years) and older women (80–90 years). It was indicated in the study that the HNR values were quite stable in young and middle-aged women, and markedly decreased in elderly participants. This finding coincides with the current finding as it also referred that HNR did not change significantly and showed stability in its values over the ages of 21–50 years. The study by Dehqan et al¹² also supports this result. In the present research, significant gender differences are found in HNR. This finding is opposed by the previous findings reported by Toran et al,¹⁰ and supported by those reported by Dehqan et al.¹² It can be argued that HNR values remain stable in the younger and middle-aged adults and decrease in elderly people (above 60 years). Furthermore, men exhibit lower values of HNR than do women.¹²

Previously, the data suggested by Williamson¹³ in his blog was used as norms during acoustic analyses in Pakistan. The current findings and previously followed data are presented below. The mean values for F₀, relative jitter, and shimmer local are found to be similar in both data. For HNR, Williamson¹³ has mentioned that mean value should be less than 20 for normal voice, but the current study has provided mean HNR values for normal voices in men and women (21–50 years) to be 22.08 dB and 25.87 dB, respectively (Table 11).

As the main outcome of the present research, normative values of studied acoustic parameters are generated for Pakistani men and women with in the age brackets of 21–30, 31–40, and 41–50 years. These findings can be used as norms for the comparison of clinical data for voice assessment.

TABLE 11.
Comparison of Suggested Data by Williamson¹³ and Current Findings

	Suggested Normative Data for Praat (Williamson, 2014)		Normative Figures from Current Study	
	Men	Women	Men (21–50 y)	Women (21–50 y)
Mean F0 (Hz)	128	225	131.04	222.68
Relative jitter (%)		≤1.04	0.41	0.34
Shimmer local (%)		≤3.81	3.17	2.40
HNR (dB)		<20	22.08	25.87

CONCLUSION

This research is the first indigenous study to explore the acoustic parameters in normal adult voices. The results of this study are consistent in some aspects with the previous studies in literature conducted for other populations, and with different analyses programs. No significant age differences are found on any of the acoustic measures. Significant gender differences are found in F₀, absolute jitter, relative jitter, jitter PPQ5, shimmer APQ5, and HNR. Furthermore, age and gender showed significant interaction on all the jitter measures, with an increase in women between the ages of 31 and 40 years, decrease in women aged 41–50 years, with a decrease in men between the ages of 31 and 40 years, and increase in men aged 41–50 years. It may be concluded that women have more controlled voices between the ages of 41 and 50 years compared with men in the same age band. The normative values explored in this study may assist in the clinical voice diagnosis, assessment, for monitoring progress in the treatment, and as a reference point for future studies in this domain.

IMPLICATIONS

Being the first clinical voice research in Pakistan, this study extends the literature based on normative acoustic measures of different populations. It has also provided the norms of voice parameters for Pakistani adult males and females. Also, the age differences studied in men and women separately may provide a deep insight about the influence of aging in both genders to identify changes occurring because of healthy aging as well as the ones caused by pathologies. The results can also be used as a reference for comparison in future studies concerning voice parameters of adolescents and older adults to seek their alterations closely over the healthy aging process.

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