Normative Values of Voice Analysis Parameters With Respect to Menstrual Cycle in Healthy Adult Turkish Women

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Summary: Objective/Hypothesis. Objective measurements are quite important for assessment of voice disorders. The first aim of this study was to establish a prototype database of normative values of voice analysis parameters in healthy Turkish adult female population. The second aim was to evaluate the variations of these parameters during physiological menstrual cycle.

Study Design. This is a prospective, single-blind study.

Methods. Eighty-nine healthy women (mean age, 31.5 ± 6.0 years) with normal physical findings and without vocal abuse or dysphonia were participated. Detailed physical and videostroboscopic larynx examination was done. Participants' voice samples of sustained /a/ and /i/ vowels were recorded, and voice analysis was done. GRBAS scale was done by four otolaryngologists, and subjects were asked to score their own voice quality using Voice Handicap Index-10 (VHI-10) at the premenstruation, during menstruation, and postmenstruation periods.

Results. Eighty-nine healthy Turkish women's some normative acoustic vocal parameters of three different phases of menstrual cycle were reported. The data indicated that during the premenstruation period; the mean jitter %, shimmer % and noise-to-harmonic ratio values were significantly higher than that of other two periods. Variations of computerized acoustic vocal analysis parameters through menstruation cycle were in concordance with the perceptual voice assessment (GRBAS) and the questionnaire of subjects' perception of their own voices (VHI-10).

Conclusions. In this study the normative values of voice analysis parameters of healthy adult Turkish women was reported. Adding computerized voice analysis parameters may improve the assessment and screening of voice in routine clinical practice because this is a simple and reliable method. Evaluation of voice can be performed regardless of the phases of menstrual cycle, but not performing acoustic analysis during the premenstrual period may prevent some of the unintended errors.

Key Words: Voice analysis–Female–Menstruation.

INTRODUCTION

Perceptual voice quality evaluation by experienced listeners is still considered to be the most reliable method in evaluation of pathologic voices although it has the lack of objective reproducibility. Nowadays, objective acoustic analysis with different computer-based systems is also an essential part of the evaluation of voice disorders as subjective evaluations performed by the clinicians and/or patients with some questionnaires and scales.[1] It is quite important to have objective, quantitative criteria in diagnosis and follow-up. Acoustic analysis may give some data to the clinicians that may aid a more sensitive diagnosis and increase the quality of follow-up during surgical interventions and voice therapy.[1,2] Moreover, this method also has the advantages of rapid and easy applicability, ponderability, and repeatability.

It is reasonably expected that people speaking different languages in different countries have different voice features because of the physical and cultural differences. As a matter of fact, in evaluation of voice disorders, principal features of the patient such as age, gender, job, and cultural context should not be omitted. To diagnose a voice as pathologic, first, the features of normal voice should be determined.[3] Therefore, many countries reported their own normative data of some voice parameters belonging to the adults in the literature.

During the evaluation of voice defects, the most commonly used voice analysis parameters belong to the frequency, intensity, and harmonics of the voices together with the parameters reflecting the alterations of these parameters between glottal cycles.[4] In literature, there are many studies reporting the features of pathologic voices, but there is an absence about the normal voice features of healthy Turkish women. The main aim of this study was, by analyzing voices of healthy adult women of Turkish population without any voice abnormality, to establish a database of baseline normative voice values which can be used in evaluation of patients admitted with voice faults, in identification of pathologic voice, and in comparison with the normative data of other countries.

Larynx is an organ that shows structural changes lifelong, and one of the causes of these changes is the sex hormones. Alterations in blood levels of sex hormones may affect the voice of women. It is reported that women may experience a voice change 4–5 days before menstruation which is called as premenstrual vocal syndrome.[5] During menstrual cycle, with a

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decrease in estrogen levels, because of the alterations in the content of connective tissue of vocal folds, character of mucosal secretions and muscle tonicity may cause voice changes, especially reduction in voice stability. In clinical practice, symptoms about the vocal changes during menstrual cycles and postmenopausal period are reported in professional voice users.[5,6] The secondary aim of this study was to investigate the probable voice alterations in healthy women with repeated analysis in different periods of menstrual cycle and by this way to prevent the errors that may take place during the diagnosis and treatment of voice disorders in women.

METHODS

This prospective, single-blind study was carried out at the voice disorders unit of otorhinolaryngology department at a research and educational hospital. It was approved by the research ethics committee (27.02.2012/01/32). Each case was verbally informed by the specialists in a comprehensive way and signed the informed consent form. The participants were native Turkish speaker women who defined their voices as normal. Detailed medical and voice habituation history was obtained via a detailed questionnaire prepared just for this study. Detailed otolaryngologic and neurologic examination was performed. Self-assessment of voice quality was scored using Turkish version of Voice Handicap Index-10 (VHI-10). VHI-10 is a questionnaire composed of 10 questions. Subjects give a point of 0–4 for each question. Increased scores define increased problems.[7]

Perceptual voice quality was evaluated by GRBAS scale by four experienced specialists who did not know the subjects. GRBAS is a reliable and valid scale which is universally used for auditory-perceptual voice evaluation. GRBAS scale consists of five parameters: grade (G), roughness (R), breathiness (B), asthenia (A) and strain (S). For each parameter, four different scores from 0 to 3 are given according to the severity of dysphonia (0 is normal, 1 is slight degree, 2 is medium degree, and 3 is high degree of severity).[8] GRBAS scoring method was performed by judges over samples of a reading passage in Turkish which comprises 219 words with rich and balanced phonemes. The compatibility between evaluators was analyzed using Fleiss Kappa and intraclass correlation before the study, and it was found out that this compatibility was statistically significant (82%, $P = 0.01$). If subject's initial VHI-10 score was ≥ 2 and mean GRBAS score was ≥ 1, the subject was not included in the study. Other exclusion criteria were as follows: history of smoking, intensive alcohol consumption, being a professional voice user, history of any respiratory, neurological, psychiatric, and endocrinologic diseases, laryngeal surgery, head and neck trauma, radiotherapy to head and neck region, chemotherapy, hearing impairment, voice therapy, vocal training, any vocally abusive or misusive behaviors, any laryngopharyngeal reflux complaint, using oral contraceptive, irregular menstrual cycles, any sign of postmenopause. Videolaryngostroboscopy (VLS) examination and voice analysis were performed in three different times. There were no sign of upper airway infection during evaluation. The first evaluation was in between the second and fifth days of menstruation, the second analysis was in postmenstruation period (between 10th and 14th days of menstrual cycles) while the third investigation was in premenstruation (between 22nd and 28th days of menstrual cycles) periods. VLS procedure was done (Xion EndoStrob DX, Berlin, Germany) by an otolaryngology specialist. If a mucosal waveform irregularity was recognized, subject was not included in the study. Voice samples were recorded in a sound-insulated room at a sound level that patients feel themselves relaxed and upright seated with high-quality omnidirectional microphone (Shure SM48, Niles, USA). The distance between the microphone and mouth was adjusted to 15 cm approximately. Microphone was positioned 90° to the mouth. Each patient was given a short practice period before the first recording to adapt to procedure. Subject was instructed to phonate sustained vowels \a\ and \i\ at a habitual pitch and comfortable loudness for 5 seconds at least. The task was repeated three times for each subject, and each trial was captured on hard disk at a 44.100-Hz sampling rate and a 16-bit resolution. *Computerized Speech Lab* (KayPENTAX CSL model 4500; Montvale, USA) software (CSL main program and multidimensional voice programme) was used to capture and analyze the voice samples. The beginning and at the end of 1 second of samples were extracted to avoid unintended irregularities and variability on voicing onset and offset. The mean values then were calculated for each subject. Eleven acoustic parameters of voice samples were fundamental frequency (*F*0), intensity (Int), jitter percent (Jitt), pitch period perturbation quotient (PPQ), shimmer percent (Shim), amplitude perturbation quotient (APQ), noise-to-harmonic ratio (NHR), relative average perturbation (RAP), voice turbulence index (VTI), cepstral peak prominence (CPP), and maximum phonation time (MPT). MPT was calculated as the measurement of the time periods of vowels \a\ and \i\ told after maximum inspiration. The longest time of the three different measurements was regarded as the MPT. A 2048-point Fast Fourier Transformation was used for the data which were sampled at the rate of 22 kHz, and frame duration was 50 ms while calculating CPP.

SPSS Version 17.0 was used for statistical analysis. The correlation analysis between variables was measured via Spearman correlation test, changes between different time periods within the group were evaluated via Friedman and Wilcoxon signed rank test, the comparison between groups in different time periods was evaluated via Mann-Whitney *U* test. The numerical results were submitted as mean ± SD. Statistical significance level was determined as $P < 0.05$.

RESULTS

The data of 89 adult women suitable for the criteria with a mean age of 31.5 ± 6.0 years (minimum 20, maximum 42 years) were assessed. The vocal analysis parameters of subjects with sustained /a/ and /i/ vowels during, after, and before menstruation are summarized in Table 1. The *P* values about the statistical significance of differences of these parameters determined in three different periods of menstrual cycle are summarized in Table 2.

TABLE 1.
The Vocal Analysis Parameters of Subjects With /a/ and /i/ Vowels in Three Different Periods of Menstruation

Phase of Menstruation	Menstruation /a/	Postmenstruation /a/	Premenstruation /a/	Menstruation /i/	Postmenstruation /i/	Premenstruation /i/
F_0	226.4 ± 24.1	223.9 ± 23.4	213.4 ± 20.9	237.7 ± 18.7	233.9 ± 15.1	228.7 ± 16.8
MPT	16.6 ± 2.9	16.4 ± 2.6	15.9 ± 2.3	16.9 ± 1.9	16.7 ± 2.0	17.0 ± 2.2
Int	62.9 ± 4.0	62.8 ± 3.8	63.0 ± 3.7	65.3 ± 3.8	66.0 ± 4.2	66.6 ± 4.0
Jitt	0.68 ± 0.37	0.67 ± 0.25	0.70 ± 0.20	0.69 ± 0.31	0.68 ± 0.29	0.72 ± 0.18
Shim	2.25 ± 0.43	2.11 ± 0.49	2.32 ± 0.62	2.04 ± 0.34	2.00 ± 0.37	2.19 ± 0.56
NHR	0.11 ± 0.20	0.11 ± 0.24	0.13 ± 0.20	0.11 ± 0.20	0.11 ± 0.24	0.13 ± 0.19
RAP	0.46 ± 0.26	0.45 ± 0.28	0.53 ± 0.17	0.40 ± 0.20	0.43 ± 0.21	0.43 ± 0.19
VTI	0.041 ± 0.012	0.041 ± 0.011	0.043 ± 0.015	0.039 ± 0.011	0.039 ± 0.011	0.037 ± 0.010
APQ	1.34 ± 0.36	1.35 ± 0.30	1.35 ± 0.33	1.20 ± 0.31	1.16 ± 0.30	1.23 ± 0.32
PPQ	0.42 ± 0.12	0.41 ± 0.11	0.41 ± 0.10	0.38 ± 0.10	0.39 ± 0.10	0.37 ± 0.09
CPP	1.64 ± 0.063	1.64 ± 0.074	1.61 ± 0.075	1.62 ± 0.059	1.62 ± 0.059	1.60 ± 0.055

Abbreviations: F_0, fundamental frequency; MPT, maximum phonation time; Int, intensity; Jitt, jitter percent; Shim, shimmer percent; NHR, noise-to-harmonic ratio; RAP, relative average perturbation; VTI, voice turbulence index; APQ, amplitude perturbation quotient; PPQ, pitch period perturbation quotient; CPP, cepstral peak prominence.
Note: Values are expressed as means ± SD.

There was not a significant difference between mean F_0 values of /a/ and /i/ vowels in comparison of results of menstruation period with postmenstruation. However, when these periods were compared with premenstruation period, there was a statistically significant decrease in mean F_0 values during premenstruation. In all three periods, F_0 of /i/ vowel was higher than that of /a/ vowel in all.

There was not a statistically significant alteration in mean MPT values, calculated in three different periods of menstruation.

It was determined that, the mean intensity value of /a/ and /i/ vowels does not show significant alterations in three different periods of menstruation. The mean intensity of /i/ vowel was significantly higher than that of /a/ vowel in all periods.

The mean Jitt and Shim values of premenstruation period were higher than those of other periods. These differences were statistically significant for both /a/ and /i/ vowels between premenstruation and postmenstruation periods. The mean Jitt and Shim values of menstruation period were not significantly different when compared with premenstruation and postmenstruation periods.

The mean NHR value of premenstruation period was higher than that of other periods. This increase was statistically significant for both /a/ and /i/ vowels between premenstruation and

TABLE 2.
The *P* Values About the Significance of Differences Between Vocal Analyses Parameters Determined in Three Different Periods of Menstrual Cycle

Dual Comparison of Phases	I	II	III
F_0	1.000*/0.186†	0.010*/0.000†	0.030*/0.000†
MPT	0.621*/0.290†	0.680*/1.000†	0.680*/0.620†
Int	1.000*/0.390†	0.439*/0.340†	0.701*/0.300†
Jitt	0.068*/1.000†	0.169*/1.000†	0.021*/0.013†
Shim	0.161*/0.218†	1.000*/0.117†	0.018*/0.017†
NHR	1.000*/0.741†	0.031*/0.040†	0.000*/0.000†
RAP	1.000*/0.896†	0.069*/0.524†	0.066*/1.000†
VTI	1.000*/0.870†	1.000*/0.280†	0.893*/0.189†
APQ	1.000*/0.720†	0.871*/0.516†	0.035*/0.021†
PPQ	1.000*/0.874†	0.915*/0.310†	0.167*/0.030†
CPP	1.000*/0.963†	0.856*/1.000†	0.456*/0.658†

Abbreviations: F_0, fundamental frequency; MPT, maximum phonation time; Int, intensity; Jitt, jitter percent; Shim, shimmer percent; NHR, noise-to-harmonic ratio; RAP, relative average perturbation; VTI, voice turbulence index; APQ, amplitude perturbation quotient; PPQ, pitch period perturbation quotient; CPP, cepstral peak prominence.
Notes: Comparisons of I: menstruation with postmenstruation, II: menstruation with premenstruation, and III: postmenstruation with premenstruation periods.
$P \leq 0.05$ refers to statistical significance.
* The *P* value of analysis data of vowel /a/.
† The *P* value of analysis data of vowel /i/.

postmenstruation and between premenstruation and menstruation periods. There was not a statistically significant difference in regards to the NHR values between menstruation and postmenstruation periods.

The alterations in RAP and VTI values of both /a/ and /i/ vowels of all three periods were not statistically significant.

The differences in APQ and PPQ levels were statistically significant for both /a/ and /i/ vowels between premenstruation and postmenstruation periods. The APQ and PPQ values of menstruation period were not significantly different when compared with premenstruation and postmenstruation periods.

The differences of CPP values of both /a/ and /i/ vowels of all three periods were not statistically significant.

GRBAS score of all cases in menstruation and postmenstruation periods was 0. In premenstruation period, GRBAS scores were as follows: G1 for two cases, R1 for eight cases S1 for three cases. The total GRBAS score was 2 in two cases and 1 in nine cases (mean value 0.146) in evaluation of cases in premenstruation period.

The VHI-10 score was 1 in three cases of menstruation period, 1 in one case of postmenstruation period, and 2 in four cases and 1 in six cases of premenstruation period. The mean VHI-10 score was 0.034 in menstruation, 0.011 in postmenstruation, and 0.157 in premenstruation period.

DISCUSSION

Clinical evaluation of voice disorders is still essentially based on subjective-perceptive criteria. The lack of objectivity and the one-sidedness of this approach arouses the necessity for measurable and recordable methods. Acoustic voice analysis that was developed with this aim supports the objective, convincing, and repeatable management of voice disorders, and it can be easily done all over the world.[1] The sustained vowels (/a/, /e/, or /i/) are classical and widely used materials for acoustic analysis and this evaluation, and sustained vowel analysis is a good substitute for sentence analysis although it may not sufficiently reflect real-life speech.[9] Vowel sounds are produced by styling of the articulator structures with position changes while the vocal tract is open, and during this period, there is not a significant construction in airway. Sustained vowel sounds which have stable fundamental frequencies and intensities provide a stationary linear source-filter coupling. For this reason, stable vowel sounds are appropriate acoustic materials for the voice analysis.[10] There is not a consensus whether different vowel sounds produce different effects on acoustic analysis or not. It has been indicated that, collecting normative data of different languages for each vowel sound may aid in this topic. In a study of Horii[11], comparing jitter and shimmer values of eight different sustained vowels, any difference was not determined. For this reason, producing a standard protocol for a few sustained vowel sounds may be more useful for the clinical practice. Typically, front vowels such as /a/, /i/, and /e/ are used in clinical and research acoustic tasks. However, specific normative values for different vowels have not been established to date. Therefore, in commenting acoustic measurements, one should be very cautious.[12] The data presented in this study are obtained with the analysis of a high-front vowel of /i/ and a midfront vowel of /a/ for simplification of the procedure.

Essential physical properties of human voice are frequency, intensity, and harmonics. F_0 of the vocal folds' vibration corresponds to the number of glottic cycles per second and reflects habitual pitch. F_0 may reflect some data about the gender, age, and height of the cases.[13] Its value of 150–250 is considered normal for women. F_0 is determined by vocal folds' length, tension, and mass. As F_0 rises, the vocal folds are lengthened and tension increases and their mass decreases.[14] When the mean F_0 values determined in this study are compared with the data of other studies performed in different countries (Table 3), this range was similar to our own results. The F_o parameter of vowel /i/ was higher than that of vowel /a/. The reasons of this increase may be amplified intrinsic tongue muscle contraction, raised tongue, increased tension of vocal folds, and narrow construction of the high vowels.[15,22]

Intensity is a force or stress with which a sound is produced and is the attribute of loudness of the sound to the listener. It is

TABLE 3.
Normative Data for F_0 Among Different Ethnic Groups

Study	Ethnic Group	/a/	/i/
Tatar et al	Turkish	220.23 ± 21.30	231.23 ± 17.60
Finger et al[14]	Brazilian	210.92 ± 20.17	n/a
Dehqan et al[15]	Iranian	214.64 ± 1.60	228.06 ± 1.50
Wang and Huang[16]	Taiwanese	213.40 ± 25.40	n/a
Guimarães and Abberton[13]	Portuguese	212.50 ± 6.60	225.50 ± 5.50
Ting et al[17]	Malaysian Chinese	206.56 ± 2.99	209.40 ± 20.18
Sapienza[18]	White American	214.90 ± 24.51	n/a
	African American	223.10 ± 29.41	n/a
Natour and Wingate[19]	Jordanian	231.13 ± 20.86	n/a
Andrianopoulos[20]	Indian	251.64 ± 34.23	262.17 ± 37.23
	Caucasian	233.46 ± 27.61	242.35 ± 25.01
Toran and Lal[21]	Nepalese	n/a	246.45 ± 2.55

Abbreviation: n/a, not available.
Note: Values are expressed as means ± SD.

usually expressed in decibel (dB), and its expected normal value in women is between 63 and 75 dB. In this study, the intensity values were determined to be lower than that of the studies of Moon et al[9] (the mean for /a/ 86.03 dB), Wang and Huang[16] (the mean for /a/ 77.8 dB), and Brockmann et al[23] (the mean for /a/ 73.2 and for /i/ 75.0 dB) but higher than the study of Franca[24] (57.3 dB).

For a normal sound signal, it has been expected to be periodic with a minimum frequency and amplitude variations between glottal cycles. Cycle-to-cycle perturbation parameters reflect the variations of sound signals on glottal cycles, and they correlate with the perceived roughness and hoarseness in the voice.[12,23] Among these perturbation parameters, the ones associated with the frequency and the intensity of the voice are the chief parameters. At least 100 periods are required to perform perturbation measurements, and therefore, for this measurement of a sound with main frequency of 100 Hz, a voice record of at least 1 second is necessary. These calculation could be affected by many factors including the age, gender, and the software used, and they could not be standardized yet.[12,23,25] These parameters increase in many neurologic diseases causing phonatory imbalance and in laryngeal disorders.[26]

Frequency perturbation parameters show frequency alterations in consecutive periods, and the most commonly used ones are the absolute and percentage jitter, RAP, and PPQ. Because absolute jitter, which is obtained with the mean of the absolute value of the difference between each period with the consecutive one, may show alterations with the main frequency, to increase the reliability of the measurement, jitter %, which is obtained with the division of the absolute jitter to the mean period, may be used. It is measured in %, and its normal value is generally reported to be <1.[27] During records, to prevent the effects of main frequency changes produced with the voice screen alterations on jitter values, three periods of smoothing are performed. The smoothing reduces the sensitivity of perturbation parameters to pitch and intensity extraction errors. In calculation of RAP, instead of differences of two consecutive periods, the difference between the mean of the three periods with the median of these three values is regarded. In PPQ calculation, dissimilar with the RAP, five periods of correction are accomplished instead of three. There is not universally accepted normative values for RAP and PPQ.[27] Amplitude perturbation parameters show the involuntary amplitude differences between consecutive periods, and the most commonly used ones are the absolute and percentage shimmer and APQ.[28] Because absolute shimmer, that is calculated by taking the mean of the peak and the following amplitudes of each period, may be effected from amplitude variations, more reliable parameters of shimmer % and APQ calculations are performed. Shimmer % value is obtained by dividing the mean absolute value of the intensity difference of each period with the consecutive one by mean period intensity. Its unit is %, and in normal voices, it is <3%. Moreover, there are also shimmer parameters that are obtained by three, five, eleven, and fifteen periods of smoothing.[27–29] The comparison of perturbation values of this study with the other studies in literature is summarized in Table 4.

The perturbation values determined in our study were not significantly different from other values reported in literature. It is thought that the differences in studies may be due to the differences in software. However, Finger et al[14] reported that the differences among acoustic voice analysis software were minimal.

Spectral parameters of the voice analysis may show turbulence noise produced by inadequate glottic closing and increase or decrease of high-frequency harmonics. They are not specific for any cycle and include amplitude and frequency perturbations. Among these spectral parameters, the chief ones are harmonics-to-noise ratio, NHR, normalized noise energy, VTI, soft phonation index, and CPP. NHR globally measures noise in signal, including contributions of jitter, shimmer, and turbulent noise. NHR is the average energy ratio of the in-harmonic components (range, 1.5–4.5 kHz) to the harmonic components (range, 70–4.500 Hz). As the degree of hoarseness increases,

TABLE 4.
Comparison of Perturbation Measurements Among Different Studies

	/a/					/i/				
Study	Jitt	Shim	RAP	APQ	PPQ	Jitt	Shim	RAP	APQ	PPQ
Tatar	0.68	2.22	0.48	1.34	0.41	0.69	2.07	0.42	1.19	0.38
Dehqan et al[15]	0.22	1.21	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Franca[24]	0.79	4.00	n/a	n/a	n/a	0.76	3.34	n/a	n/a	n/a
Finger et al[14]	0.42	2.96	0.25	1.78	0.25	n/a	n/a	n/a	n/a	n/a
Toran and Lal[21]	n/a	n/a	n/a	n/a	n/a	0.16	1.60	n/a	n/a	n/a
Brockmann et al[23]	0.37	0.46	n/a	n/a	n/a	0.32	0.65	n/a	n/a	n/a
Ting et al[17]	0.44	2.09	0.26	1.53	0.26	0.33	1.40	0.19	1.14	0.19
Çelik et al[30]	0.28	4.33	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Andrianopoulos et al[20]										
African American	1.09	0.99	0.29	0.66	0.27	0.47	1.16	0.29	0.78	0.26
Indian	0.88	1.26	0.53	0.67	0.52	0.55	1.59	0.55	1.06	0.51

Abbreviations: Jitt, jitter percent; Shim, shimmer percent; RAP, relative average perturbation; APQ, amplitude perturbation quotient; PPQ, pitch period perturbation quotient; n/a, not available.
Note: Values are expressed as means.

the noise component increases and replaces the harmonic structure. Increased values of NHR are interpreted as increases in spectral noise which can be attributable to turbulent noise, subharmonic components, and voice breaks.[29,31] Finger et al,[14] Franca et al,[24] and D'haeseleer et al[32] determined the normative NHR values as 0.13 ± 0.23, 0.12 ± 0.025, and 0.12 ± 0.02, in their studies, respectively, and these values were very common with the results of this study (0.11 ± 0.21). VTI is the ratio of high-frequency noise energy to the total energy, and it is a parameter showing high-frequency noise in voice. VTI is related to turbulence caused by abnormal closure of vocal folds.[24] As a parameter rarely reported in studies, there is not enough data about the normative values of VTI. Cepstrum is the Fourier conversion of the logarithm of the Fourier conversion of a voice signal meaning that it is a kind of reverse spectrum. Hence the word '*cepstrum*' was derived from the word '*spectrum*'. CPP is the height of the first spectral peak in dB during the cepstrum measurement.[33] Cepstrum analysis, that is Fourier transformation of a spectrum obtained by Fourier transformation of an acoustic signal, is a parameter reported to be more reliable in measurement of periodicity of voice than frequency and amplitude perturbations because this measurement is not effected by the errors of the F_0 measurement and reflects the composition of harmonics better. With a disrupt in voice quality, CPP value also decreases.[34,35] The data of this study are compatible with the mean CPP values of healthy women determined in two different studies of Balasubramanium et al[36,37] (1.68 ± 0.045 and 1.70 ± 0.052).

Among aerodynamic analysis methods that aim to determine the pulmonary functions that play a generator function in phonation and closing ability of vocal folds, the most certainly measurable ones without the requirement of any device are the MPT and s/z ratio.[15,16] Among aerodynamic analysis, the most commonly used one is the MPT. MPT is the longest duration of phonation after a deep inspiration and measured in seconds. Normative value for MPT was reported as 15–25 seconds. It is measured in seconds, and women's mean normal value of MPT is 15–25 seconds.[27] Wang and Huang[16] reported that the mean MPT of Taiwanese Chinese women (20–40 years old) was 22.6 seconds, whereas Çelik et at[30] found the mean MPT as 19.2 seconds and Dehqan et al[15] reported the mean MPT as 18.5 seconds. When these values are compared with the results of our study (mean 16.3 seconds), they were higher than our results.

It was suggested that some women, especially the professional ones, may experience some voice changes such as vocal fatigue, decreased intensity, and alterations of harmonics during premenstrual period.[5] Studies about this topic are generally performed with professional voice performers, and these results belong to this population. Silverman and Zimmer[38] suggested premenstrual hoarseness as a very rare condition among young women with no vocal training. The causes of menstruation-associated voice changes may be edema and increased vascularity in vocal fold stroma due to the alterations in blood levels of sex hormones during menstrual cycle; more viscous and acidic production of mucous in lower amounts; mucosal dryness; decreased tonicity of vocal muscles. Histological changes that may affect the voice may also be determined with VLS. In VLS performed in premenstrual and menstrual periods, edema, microvarices, and decrease in wave amplitude in vocal folds may be determined.[5] In this study, we did not determine any pathologic changes such as these in VLS investigations performed in different menstrual periods of patients.

Raj et al[39] found out that the menstrual phase with the highest estrogen level was seem to have the best voice quality as compared with premenstrual phase with the lowest levels. Çelik et al[30] reported that acoustic voice analysis measurements (F_0, intensity, Jitt, Shim, NHR, and MPT) do not show significant alterations in different periods of menstruation; however, in subjective evaluations (GRBAS and VHI-10), perceptual voice quality was reported to be the best in midmenstruation period but the worst in premenstrual period. In the study of Chae et al,[40] jitter was determined to be significantly higher in premenstrual period, but any significant correlation was not reported between premenstrual syndrome and the severity of the voice changes. In this study, we determined that in premenstrual period, among acoustic analysis parameters, F_0 was significantly lower and NHR was higher, and these results were thought to be due to increased mass of vocal folds. Other investigated objective voice parameters and subjective evaluations (VHI-10 and GRBAS) were determined not to alter significantly in different periods of menstruation. These results were consistent with the results of Silverman and Zimmer, Chae et al, and Çelik et al.[30,38,40]

The main limitations of this study were as follows: analyses of central and back vowels were not performed, sentence-based voice analysis was not achieved, synchronous hormone analysis was not done, and the age spectrum of the study population was narrow. Determination of normative acoustic data with larger number of patients at different age groups (children, adolescent, postmenopausal) and with different genders is warranted. The main problems about the computer-based voice analysis are the standardization difficulties due to language, culture, and software differences. For this reason, because the results of studies are not homogenous, for the standardization of voice analysis parameters, larger studies gain more importance.

CONCLUSIONS

This was the first study presenting the voice parameters of healthy adult women in Turkish population. The data of normative computerized acoustic values determined in this study may be used as reference values in evaluation of adult women admitted with voice disorders in routine clinical practice because computer software–based acoustic analysis has becoming more popular. According to the results of this study, acoustic voice analysis may be performed by omitting the menstrual period of the women with the knowledge of that minimal changes may be seen in some perturbation parameters and decreased fundamental frequency in premenstrual period. These minimal variations may imply importance for professional voice users. Further studies with large number of subjects from different populations in terms of age, sex, and profession are needed to construct a more reliable database to establish normal voice standards.

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