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Objective Voice Analysis of Mongolian Adults with a Normal Voice Across Age and Gender

Nergui Sodnompil[1,2], Ganchimeg Palamdorj[1], Byambasuren Lkhuvsandagva[2], Khorolsuren Lkhagvasuren[3], Bayasgalan Gombojav[4], Munkhtuya Tserendulam[4], Bolortsetseg Zorigtbaatar[5], Damdindorj Boldbaatar[6]

[1]Department of Otorhinolaryngology, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia; [2]Department of Otorhinolaryngology, The First Hospital of Mongolia, Ulaanbaatar, Mongolia; [3]Department of Health Policy, School of Public Health, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia; [4]Department of Graduate Studies, Graduate School, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia; [5]Department of Physiology and Molecular Biology, Ach Medical University, Ulaanbaatar, Mongolia; [6]Department of Physiology, School of Biomedicine, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia

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Corresponding Author
Damdindorj Boldbaatar, MD, PhD
Department of Physiology, School of Biomedicine, Mongolian National University of Medical Sciences, Ulaanbaatar 14210, Mongolia
Tel: +976-9999-6522
E-mail: damdindorj@mnums.edu.mn

Objectives: We aimed to standardize main vocal parameters including fundamental frequency (F0), jitter, shimmer, harmonic-noise ratio (HNR), and smoothed cepstral peak prominence (CPPs) for Mongolian adults with a normal voice across a range of age groups and genders. **Methods:** A total of 360 voice recordings belonging to adults between 20 and 79 years old were analyzed. An acoustic analysis was performed using the Praat Program with a sustained vowel /a/ or /α/. A one-way analysis of variance and an unpaired t-test were used to measure differences in voice parameters for the age groups and genders. **Results:** The mean value of F0 was higher in women (254.4 ± 17.9 Hz) compared with men (149.6 ± 15.3 Hz). The average jitter was 0.26% ± 0.12% (W = 0.25 ± 0.13) and the shimmer was 1.95% ± 0.45% (W = 2.01% ± 0.45%). The mean value of HNR was 11.9 ± 1.33 dB (W = 12.1 ± 1.36 dB) and CPPs was 16.3 dB (W = 16.1 dB). **Conclusion:** The F0 and HNR significantly increased with age for men. The F0 and CPPs decreased, whereas the shimmer and HNR increased with age in women.

Keywords: Acoustics, Voice, Mongolia, Adult, Aging

Introduction

Voice acoustic analysis has been introduced clinically to record objective data before and after surgery for voice disorders to provide a better understanding of the pathophysiology of voice production [1]. Acoustic voice analysis provides normative or fundamental data for different voice realities [2]. Normal standards are important for guiding vocal professionals. Normal voice varies widely given that it is a personal feature and no voice is equivalent to another [3, 4]. The most common parameters used in voice assessment in the literature are fundamental frequency (F0) and cycle-cycle perturbations such as jitter, shimmer, and harmonic-noise ratio (HNR) [5]. In addition, recent work in acoustic voice analysis has increasingly supported the cepstral peak prominence (CPP) [6].

F0 is the most constant and reproducible vocal parameter among all the parameters included in the voice analysis software [7]. Therefore, it is the main parameter that should be evaluated. It has also been observed that the most commonly used acoustic parameters depend on F0.

Jitter is a parameter of frequency variation from cycle to cycle. The shimmer is a time-based parameter expressed in decibels. It describes the amplitude variation of a waveform and measures the instability of the amplitude. The shimmer is expressed as the variability of the peak-to-peak amplitude in decibels [8].

HNR is a measure that quantifies the relative amount of additive noise in the voice signal. When the vocal folds are closed insufficiently, air passes through the glottis, giving rise to turbulence. The resulting friction is reflected in a higher noise level in the spectrum. HNR reflects voice quality and is a significant predictor of voice samples that are perceptually rated as rough [9].

CPP is a somewhat newer acoustic measure, one which evaluates measures the vocal signal without relying on the identification of the fundamental period [10]. It has become more common now for studies to either combine or only use CPPs, which uses Fast Fourier Transformations and is a more reliable perturbation measure for moderate to severely dysphonic speakers. CPPs, which is correlates better with perceived breathiness in voice compared with CPP, differs only by a value of 0.02 for the two age groups [11].

It is well known that voices change with age. For example, listeners are able to estimate the age of someone just by listening to a person's voice [12-13]. In women, the vocal modifications are justified by the combination of the onset of aging and the transition from menopause [14]. In males, as age advances, elastic fiber atrophy and collagenous fibers increase in the lamina propria. The intermediate layer becomes thinner, whereas the deep layer thickens. Thus, the shortening of the membranous vocal fold and increase in stiffness of the vibrating tissue causes an increase in fundamental frequency [14]. With respect to age, higher values of jitter and shimmer have been observed in men and women [15]. Noise measures have not been reported in the literature for voices without alterations. Such studies may offer important information, particularly related to vocal deterioration because of aging [9]. Significant specific gender effects were found for CPPs. In particular, significantly higher values of CPPs were found in males compared with females [16].

None of the international scientific journals have published vocal studies on the Mongolian population. The current studies were done primarily with the aim of obtaining the normative acoustic measures in Mongolian adults. We aimed to standardize main vocal parameters including fundamental frequency (F0), jitter, shimmer, harmonic-noise ratio (HNR), and smoothed cepstral peak prominence (CPPs) for Mongolian adults with a normal voice across age groups and genders.

Materials and Methods

Subjects

Data collected from a total of 360 healthy adults (180 men and 180 women) aged 20–79 years participated in this study. The subjects were Mongolian speakers from all the provinces in the Mongolian territory. Exclusion criteria involved people with a recent history of flu and allergy symptoms, previous major head or neck surgery, chemoradiotherapy, dysphonia, abnormalities of the vocal tract, and auditory problems. Study participants were also perceptually analyzed using the GRBAS (Grade, Roughness, Breathiness, Asthenia, and Strain) scale [17]. The ratings were conducted by two certified speech/language pathologists (whose interrater reliability was relatively high). Participants had no history of smoking, alcohol consumption, professional singing, or formal voice training.

Equipment and procedures

We performed an acoustic examination in a soundproof room. A vertical net sound microphone (Sound Level Meter Microphone Real SPL, IEC 651, Type II for Ling waves Voice Analyzer Software, WEVOSYS, Forcheim, Germany) was placed at a 30° angle near the subject, with a 2–3 cm distance from their lips. Electrodes were placed in front of the thyroid cartilage. A Velcro fastener was used to keep the electrodes in place. A Laryngograph Micro Processor EGG-A100 was used for the recordings. All participants were asked to take a deep breath and to phonate the Mongolian vowel /a/ or /α/ at a comfortable range, using habitual vocal pitch and loudness. The reason for choosing vowel /a/ is because fundamental frequency, signal-to-noise ratio, and nonlinear dynamic parameters may be applied to characterize /a/ as having lower frequency, higher noise, and greater nonlinear components than /i/ and /u/ [18].

The phoneme was maintained for 6 seconds in a modal registry three times. The signal was segmented with approximately 500 milliseconds from the start and end of the sound to avoid a sudden rising and falling pitch of the sound. The recordings of the phonations were saved onto a laptop after vowel production. The segmented sounds were analyzed using Praat 15 software [19]. The Praat analysis was completed using a script and 20% of the data were remeasured manually to check for reliability. Reliability testing was conducted for the sustained vowel /a/ for test-retest comparisons to determine inter-measure reliability. CPP measurements were extracted using the Power Cepstrogram from the Praat software.

Statistical analysis

SPSS 20 software was used for statistical analysis. The evaluations were done in terms of fundamental frequency, jitter, shimmer, and HNR. The Shapiro-Wilk test was conducted to determine the normality of distribution of the variables studied for F0, jitter, shimmer, HNR, and CPP, which was calculated for age and gender. A one-way analysis of variance with Tukey's post-hoc analysis was used to determine the difference between age groups. An unpaired t-test was used to determine the group mean differences between men and women for each age group.

Ethical statement

The study conforms to the ethical guidelines of World Medical Association Declaration of Helsinki. The participants of the study have given their written consent and the study was approved by the Research Ethics Committee of the Mongolian National University of Medical Sciences (No.2019/3-08). All patients provided written informed consent before participating in the study.

Results

A total of 360 participants (180 men and 180 women) were evaluated for the acoustic analysis. The tables below provide a statistical summary of the study participants by age groups and genders. The Shapiro-Wilk test revealed ($p > 0.05$) a normal distribution.

The participants were divided into six age groups (G1=20–29 years, G2=30–39 years, G3=40–49 years, G4=50–59 years, G5=60–69 years, and G6=70–79 years) for both genders. There were an equal number of people from each gender and age group. Identical representative samples from the age groups and both genders were included in the study (Table 1).

The Tukey post-hoc test revealed a significant increase in F0 and HNR with age in men. All other parameters were not statistically different (Table 2).

The results indicate that F0 decreased in the 40–49 age group. The Tukey post-hoc test indicated that F0 and CPPs decreased with age in women. The shimmer and HNR had a tendency to increase relative to age in women (Table 3).

An unpaired t-test was conducted to examine the difference of gender on the main vocal parameters. The results showed no significant difference on the bases of gender, except the F0 (Table 4).

Table 1. Descriptive statistics of participants` age and gender.

			Men			Women	
Age groups	Age (years)	N	Mean	SD	N	Mean	SD
G1	20–29	30	24.36	2.23	30	24.16	2.46
G2	30–39	30	33.68	3.67	30	34.12	3.24
G3	40–49	30	47.32	4.89	30	43.44	2.83
G4	50–59	30	53.39	2.74	30	56.85	3.01
G5	60–69	30	63.6	3.92	30	65.12	2.62
G6	70–79	30	72.04	6.17	30	73.77	2.78
Total	29–79	180	48.56	10.31	180	52.4	11.14

SD=standard deviation

Table 2. Acoustic parameters in different age groups of men.

	Men (n = 180)						
Age groups	**G1 (n = 30)**	**G2 (n = 30)**	**G3 (n = 30)**	**G4 (n = 30)**	**G5 (n = 30)**	**G6 (n = 30)**	***p-value**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
F0[a]	145.5 ± 13.8	147.1 ± 11.7	147.2 ± 15.3	148.9 ± 14.4	151.9 ± 17.4	156.8 ± 16.6	0.045
Jitter	0.27 ± 0.14	0.29 ± 0.14	0.24 ± 0.12	0.22 ± 0.11	0.26 ± 0.08	0.28 ± 0.12	0.156
Shimmer	1.9 ± 0.43	1.8 ± 0.49	2.03 ± 0.44	1.89 ± 0.38	2.03 ± 0.43	2.06 ± 0.49	0.176
HNR[b, c, d, e, f, g, h]	11.3 ± 1.16	11.2 ± 1.26	11.61 ± 1.13	12.1 ± 1.12	12.7 ± 1.12	12.6 ± 1.36	0.000
CPPs	16.5 ± 1.52	16.5 ± 1.56	16.2 ± 1.56	16.4 ± 1.38	15.9 ± 1.65	16.0 ± 1.78	0.542

F0=fundamental frequency; HNR=harmonic-noise ratio; CPPs=smoothed cepstral peak prominence; SD=standard deviation; *One-way analysis of variance result; Tukey post hoc comparison age groups: [a]G1 vs. G6, p = 0.04; [b]G1 vs. G5, p < 0.001; [c]G1 vs. G6, p < 0.001; [d]G2 vs. G4, p=0.04; [e]G2 vs. G5, p < 0.001; [f]G2 vs. G6, p < 0.001; [g]G3 vs. G5, p = 0.004; [h]G3 vs. G6, p = 0.009

Table 3. Acoustic parameters in different age groups of women.

	Women (n = 180)						
Age groups	**G1 (n = 30)**	**G2 (n = 30)**	**G3 (n = 30)**	**G4 (n = 30)**	**G5 (n = 30)**	**G6 (n = 30)**	***p-value**
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
F0[a, b]	261.3 ± 15.9	261.3 ± 14.7	253.9± 19.0	253.8 ± 18.6	248.5 ± 14.9	247.7 ± 17.2	0.005
Jitter	0.23 ± 0.18	0.25 ± 0.15	0.25 ± 0.11	0.24 ± 0.09	0.28 ± 0.13	0.27 ± 0.12	0.716
Shimmer[c, d]	1.93 ± 0.42	1.91 ± 0.36	1.92 ± 0.45	1.89 ± 0.37	2.19 ± 0.46	2.25 ± 0.52	0.001
HNR[e, f]	11.4 ± 1.17	11.4 ± 1.06	12.3 ± 1.11	12.1 ± 1.24	12.3 ± 1.62	12.9 ± 1.34	0.000
CPPs[g]	16.8 ± 1.42	16.6 ± 1.54	16.1 ± 1.5	15.8 ± 1.17	15.9 ± 1.36	15.6 ± 1.51	0.013

F0=fundamental frequency; HNR=harmonic-noise ratio; CPPs=smoothed cepstral peak prominence; SD=standard deviation; *One-way analysis of variance result; Tukey post hoc comparison age groups: [a]G1 vs. G6, p = 0.03; [b]G2 vs. G6, p < 0.03; [c]G2 vs. G6, p = 0.02; [d]G4 vs. G6, p = 0.01; [e]G1 vs. G 6, p < 0.001; [f]G2 vs. G6, p < 0.001; [g]G1 vs. G6, p = 0.01

Table 4. Comparison of vocal parameters between men and women.

	Men (n = 180)	**Women (n = 180)**	**p-value**
	Mean ± SD	Mean ± SD	
F0	149.6 ± 15.3	254.4 ± 17.9	0.003
Jitter	0.26 ± 0.12	0.25 ± 0.13	0.265
Shimmer	1.95 ± 0.45	2.01 ± 0.45	0.089
HNR	11.9 ± 1.33	12.1 ± 1.36	0.059
CPPs	16.2 ± 1.58	16.1 ± 1.47	0.578

F0= fundamental frequency; HNR=harmonic noise ratio; CPPs=smoothed cepstral peak prominence; SD=standard deviation; Unpaired t-test

Discussion

In this study, we analyzed normal voices of Mongolian adults aged 20–79 years to determine the effect of age and gender on various acoustic measures including F0, jitter, shimmer, HNR, and CPPs for the sustained vowel /a/. Standardization of the acoustic data has significant implications for voice clinicians, students of speech and language pathology, and instrument manufacturers [15-21].

F0 is one of the most frequently used measures to characterize human voice. It provides cues about age and gender [3]. Data from studies that assessed vocal parameters using the sustained vowel /a/ were compared. The main values for F0 of Mongolian men and women were 149.6 Hz and 254.4 Hz, respectively. This was higher compared with Portuguese (M = 121.00 Hz; W = 212.50 Hz) [3], Taiwanese (M = 121.3 Hz; W = 213.4 Hz) [1], Italian (M = 113 Hz; W = 191.431 Hz) [20], Pakistani (M = 131.04; W = 225.24 Hz) [15], Iranian (M = 112.82 Hz; W = 214.64 Hz) [20], and Spanish (M = 109.99 Hz; W = 194.94 Hz) voices [22].

Meng et al. found that the mean F0 for Chinese adult men and women was 162.09 Hz and 273.88 Hz and these values were higher compared with our study [23]. Andrianopolous et al. found that the F0 values for Chinese men and women were 154 Hz and 266.73 Hz, which were similar to the Mongolian adults [24]. F0 was higher for women compared with men in this study, but increased gradually in men and decreased gradually in women with age, consistent with other studies [1, 3, 20-24]. The gender differences in F0 may be justified since there are significant anatomic differences in the larynges of men and women. A male larynx is approximately 40% larger compared with that of a woman and the vocal folds have a thicker mass [25]. We observed a similar decrease in F0 in the 40–49 age group of women as well. This may be explained by the influence of hormonal alterations associated with premenopause and menopause. As summarized by D'haeseleer et al. the menopause period may affect the laryngeal tissue, which in turn may cause muscle atrophy and edema in the vocal folds [26]. Changes in vocal quality resulting from menopause were also reported and included hoarseness, changes in vocal timbre with difficulty in reaching high frequency, and instability. The mean value of HNR was 11.9 ± 1.33 dB in men and 12.1 ± 1.36 dB in women. CPPs for men and women were 16.3 dB and 16.1 dB, respectively.

The average jitter in the present study for men and women measured 0.26% and 0.25%, respectively. This was similar to that of the Pakistani population [15]. We observed lower values of jitter in both genders compared with preexisting studies [19, 23, 24]. The results of the values for shimmer revealed that the male population had higher values (1.95%) compared with women (2.01%), which were similar to that of previous studies [23, 24]. The mean value of shimmer was greater in the Italian (M = 3.964%; W = 2.825%) [20], and Pakistani population (M = 3.18%; W = 2.44%) [15]. Delgado et al. presented similar values for shimmer (M = 2.38%; W = 1.48%) as this study [22].

The mean values for HNR were higher in women (12.1 dB) compared with men (11.9 dB). These results were in line with that of previous studies [1, 9, 21]. Italian (M = 17.323 dB; W = 19.850 dB) [20], Pakistani (M = 22.93 dB; W = 25.87 dB) [15], Iranian (M = 18.42 dB; W = 18.81 dB) [21], and Spanish (M = 22.94 dB; W = 25.63 dB) [22] studies reported higher mean HNR values compared with this study. A Taiwanese study reported similar results (M = 10.1 dB; W = 12.2 dB) [1] for HNR. Ferrand suggested that HNR is an important index of aging and HNR values increase as a person ages in other countries, which is a novel finding for Mongolians [9].

The current results for CPPs (M = 16.3 dB; W = 16.1 dB) are comparable to those from previous studies including Núñez-Batalla et al. (M = 16.0 dB; W = 16.4 dB) [27] and Angélica et al. (16.44 dB) [27, 28]. It was also higher than several previous studies [6, 10, 11, 23]. Christina et al. reported specific significant gender effects for CPPs (M = 17.18 dB; W = 15.08 dB) [17]. The present study found a difference in CPPs for women of different ages.

The main limitation to this study is the omission of controls in the determinants of acoustic parameters derived from the literature, such as the height and weight of the participants. We plan to perform electroglottography during connected speech, factoring in height and weight of the participants. To our knowledge, this is the first attempt to standardize the main vocal parameters for Mongolian adults with a normal voice across different age groups and genders. This standardized data can be used to analyze voices.

Conclusion

The average F0 values for men and women were 149.6 ± 15.3 Hz and 254.4 ± 17.9 Hz, respectively. The average jitter values for men and women were 0.26% ± 0.12% and 0.25% ± 0.13%, whereas shimmer values for men and women were 1.95% ± 0.45% and 2.01% ± 0.45%, respectively. The mean values of HNR for men and women were 11.9 ± 1.33 dB and 12.1 ± 1.36 dB. The average CPPs for men and women were 16.2 ± 1.58 dB and 16.1 ± 1.47, respectively. The F0 and HNR increased significantly with age in men. The F0 and CPPs decreased, whereas the shimmer and HNR increased relative to age in women, but not in gender, except F0.

Conflict of Interest

The authors have no conflicts of interest to declare.

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