Acoustic Parameters of Perceptually Normal Voice Production in Filipinos: An Exploratory Study Among Selected Adults in Metro Manila

Jocelyn Christina B. Marzan*, Howell Henrian G. Bayona

*Corresponding author's email address: jbmarzan@up.edu.ph

Department of Speech Pathology, College of Allied Medical Professions, University of the Philippines Manila, Manila, Philippines

RESEARCH ARTICLE

Abstract

Background and Objectives: Acoustic analysis is an objective instrumental method that makes more accurate and reliable assessments of vocal characteristics possible. The aim of the current study was to describe the vocal characteristics of Filipinos with perceptually normal voices in terms of (1) fundamental frequency, (2) intensity, (3) frequency and intensity perturbations, (4) speaking fundamental frequency range, and (5) nasalance.

Methodology: A total of 142 healthy adults aged 18 – 53 years participated in this study. The group was composed of 73 men (26.9 ± 6.4 years old) and 69 women (26.1 ± 6.5 years old). Voice samples were collected using Computerized Speech Laboratory™ (CSL; Model 4300B) during sustained phonation of vowel /a/ and spontaneous speech. Nasometer™ (Model 6200-3) was used to assess nasality while participants read plosive- and sibilant-loaded sentences.

Results and Conclusion: The average acoustic values for males were F_0 = 125.8 ± 23.4 Hz, SF_0 = 122.6 ± 15.6 Hz, SF_0 range = 85.8-269 Hz, SPL (speech) = 58.6 ± 5.3 dB, SPL (vowel) = 66.6 ± 6.2 dB, jitter = 0.92 ± 0.48%, shimmer = 2.21 ± 0.73%, nasalance = 12.5-17.1%; for females, F_0 = 196.3 ± 23.0 Hz, SF_0 = 194.8 ± 19.0 Hz, SF_0 range = 97.1-309.6Hz, SPL (speech) = 57.6 ± 4.3 dB, SPL (vowel) = 65.3 ± 4.5 dB, jitter = 1.12 ± 0.34%, shimmer = 2.7 ± 0.64%, nasalance = 13.1-19.1%. Significant differences were found between male and female subjects for F_0, SF_0, perturbation measures, and SPL during sustained phonation ($p < 0.05$). Acoustic data obtained also appear to be consistent with the results of local and international studies. While these can be used as tentative normative data for Filipinos, it is recommended that future studies be completed with more systematic analysis procedures and stringent participant selection to ensure balance for age, sex, and vocal history among subgroups.

Keywords: *voice, acoustic measures, jitter, shimmer, nasality, Filipino*

Introduction

Overall voice quality is usually described through subjective or perceptual observations. While this appears to be the most convenient approach often utilized by speech pathologists engaged in clinical practice, its reliability is influenced by standardization issues and subjective ratings. In contrast, acoustic analysis is an objective instrumental method that makes more accurate and reliable assessments of vocal characteristics possible [1]. Acoustic analysis may also aid in recognizing a vocal pathology or in monitoring changes in vocal function over time. In treatment, objective acoustic measurements can also be used to improve a client's awareness of his vocal behaviors (i.e. biofeedback) or to document progress.

Objective measurements significantly differ across cultures and gender due to linguistic, dialectal, and physiological factors [2,3]. Mandarin Chinese speakers showed higher fundamental frequencies than their Caucasian and African-American counterparts, while Hindi Indian speakers were found to have the highest shimmer values [3]. Thus, normative data need to be culturally-valid and developed locally. In the Philippine setting, published work regarding objective voice measurements is very limited. A pilot study by Delovino, Casile, and Hawson [4] attempted to provide baseline data for vocal acoustic measures involving 70 participants with no voice complaints. They acknowledged that additional data taken from the same population would be helpful to corroborate their findings.

This study presented data that, combined with the findings of Delovino *et al.* [4], contributed to the further development of norms for the production of voice among Filipinos. It also provided an initial analysis of the differences between male and female Filipino speakers as well as the possible influence of age on different acoustic voice measures. Findings from this study may serve as basis for larger and more systematic studies in the future. Normative data would ultimately be of use to otolaryngologists, speech pathologists, vocologists, and other professionals in the diagnosis and treatment of voice disorders or the development of optimal vocal performance.

Methodologies for normative voice studies share several common characteristics. Participants who are selected are usually those who have no reported history of any vocal fold pathology, hearing impairment, smoking, or any other health condition affecting voice that might be present at the time of testing [5-9]. Testing rooms are sound-treated to minimize environmental noise as noise tends to affect the fidelity of the recordings. Voice samples may be obtained from different speech tasks, such as sustained phonation of vowels, spontaneous speech, or oral reading [5,6,8,10-14]. Most studies have shown a preference for sustained vowels because these productions are easier to control and are less affected by confounding articulatory information [15]. A sample of an individual's connected speech, however, may yield fundamental frequency values that are more representative of the habitual fundamental frequency exhibited during natural conversations [11]. The data analyzed by Fitch [11] showed that fundamental frequency in isolated vowel production tended to result to fundamental frequency values 30-50 Hz higher than those obtained during spontaneous speech.

Acoustic voice analysis involves the use of instrumentation to analyze the properties of sound waves. There are several programs available commercially, such as the Computerized Speech Laboratory [CSL] (Kay Elemetrics), Visi-Pitch™ (Kay Elemetrics), SoundScope (GW Instruments), Dr. Speech (Tiger Electronics), and others. These instruments are able to transform analog signals from the recorded sample into digital signals, which allows analysis of periodicity, exclude noise portions, voice interruptions, among others. In the Philippine setting, the use of the above equipment is limited owing to their being cost-prohibitive. In interpreting findings or assessing perceptual voice characteristics, speech-language pathologists are usually involved owing to their experience in assessing and treating patients with voice disorders [12].

Acoustic voice measurements correlate with various perceptual qualities and pathological states [1]. Values typically obtained include fundamental frequency, intensity, and perturbation. These are then compared to normative data for the patient's age and sex. However, acoustic voice measurements are typically influenced by multiple factors, such as environmental noise, acquisition and analysis software, microphone, and variability among participants. Deliyski and his colleagues [16] investigated these factors and found that an environmental noise level below 30 dB distorts the voice samples of normal subjects to a point where it would be difficult to differentiate them from dysphonic subjects. They also found that fundamental frequency measurements are strongly affected by gender, intrasubject variability, and microphone type. Perturbation values were shown to be highly influenced by software systems and gender [16,17], which makes it necessary to perform subgroup analyses specific to these variables.

Fundamental frequency (F_0) measures vocal fold vibration reported in cycles per second (cps or Hertz/Hz). Fundamental frequency measured during spontaneous speech or reading is referred to as speaking fundamental frequency (SF_0). Both are related to the perception of vocal pitch. The fundamental frequency of a speaker's voice is determined by the length, tension, and mass/thickness of his/her vocal folds during voice production. The lowest and highest recorded pitch frequencies produced during the sampling tasks constitute the frequency range [18]. Values deviating from the expected range during phonation may be indicative of pathology [19]. A higher F_0 results from an increased mass per unit area of the true vocal cords, as often is the case occurs when a speaker presents with vocal fold nodules or other masses that grow along the glottal margin [19].

Intensity, amplitude, or sound pressure level (SPL) is an acoustic measure correlated with the perception of vocal loudness. The range of loudness an individual can produce is measured as the intensity range [18]. Vocal sound pressure level is determined by the degree of compression of the vocal folds medially, subglottic air pressure, as well as coordination of respiration and neural mechanisms [18,19]. Healthy speakers can vary their vocal intensity by changing their breathing patterns to create the necessary subglottal air pressures [20]. In contrast, vocal intensities are decreased for individuals with respiratory illness as a result of reduced lung volumes or for those with vocal cord paralysis due to reduced glottic resistance and closure.

Perturbation refers to a disturbance in the regularity of a waveform. Changes in vocal fold mass, tension, or vibratory characteristics may create small, rapid, cycle-to-cycle changes of period or amplitude. Perturbation correlates to perceived roughness or harshness of the voice. Jitter denotes the variation of fundamental frequency across cycles and is expressed in percent or in microseconds. On the other hand, shimmer reflects irregularities in the intensity of a signal. While normal speakers exhibit a certain amount of perturbation during voicing, in principle, its values should lie within a specific range. High perturbation values are indicative of changes in vocal fold structure and function [22]. Individuals with breathy or hoarse voices, for example, exhibit increased shimmer or jitter as they cannot sustain a relatively constant level of loudness or pitch. Another crucial acoustic measure is the harmonics-to-roise ratio (HNR) which may be used to predict dysphonia severity [23]. Normative data for the local population is lacking on this measure.

Vocal quality may also be described in terms of quality of resonance. Nasalance, expressed in percent, measures the amount of voice resonated in the nasal versus the oral cavity. It is reflective of the degree of velopharyngeal opening in voiced speech. In individuals who exhibit hypernasality or hyponasality, velopharyngeal insufficiency is often observed [24].

The objective of the current study was to describe the vocal characteristics of Filipinos with perceptually normal voices in terms of (1) fundamental frequency, (2) intensity, (3) frequency and intensity perturbations, (4) speaking fundamental frequency range, and (5) nasalance.

Methodology

Study Design

An exploratory, cross-sectional, non-experimental research design was used in this study.

Participants

A total of 142 Filipinos with ages ranging from 18 – 53 years participated in this study;73 were males (mean age = 26.9, SD = 6.37) and 69 females (mean age = 26.1, SD = 6.58). Participants were selected using convenience sampling. The participants had given their informed consent prior to testing. All participants exhibited perceptually normal speech and voice during eligibility assessment as determined by a practicing speech pathologist with 14 years of clinical experience working with voice patients. Hearing acuity was adjudged to be within normal limits based on observations during conversational interaction. While there was no reported hearing loss, participants did not undergo any formal hearing tests. Approximately 75-85% were non-smokers. A majority (>90%) of the participants reported having no chronic respiratory illnesses, acute upper respiratory tract infection, allergies, colds, or similar conditions at the time of testing or in the recent past. Several of the participants were professional voice users (e.g., teacher, therapist, singer, etc.). Table 1 summarizes the descriptive information of the participants.

Table 1. *Demographic Characteristics of the Participants*

	Males (N = 73)	Females (N = 69)
Mean age (years)[1]	26.9 [18 – 51]	26.1 [19 – 53]
Mean height (inches)	66.5 [60 – 71]	61.8 [57 – 68]
Mean weight (lbs.)	146.9 [100 – 240]	111.3 [80 – 160]
Smoking history[2], yes (%)	26	14.5
Medical history is significant for		
Asthma (%)	5.6	4.6
Chronic colds (%)	4.2	6.2
Sinus infection (%)	1.4	4.6
Hearing loss (%)	1.4	0
Others, not specified (%)	7.0	0
None (%)	80.4	84.6
Professional voice user, yes (%)	38.3	30.0

[1] Ranges are shown in brackets
[2] Pack-years and time since cessation of smoking not documented

Data Collection Procedure

Voice sampling was conducted in the National Institutes of Health (NIH) and the Clinic for Therapy Services (CTS) both located at the University of the Philippines Manila. Voice samples from 80 participant (53%) were recorded at the NIH and 71 (47%) were recorded at CTS. The recording was performed using a Shure® SM48-LC unidirectional dynamic microphone and the Computerized Speech Laboratory™ (CSL; Model 4300B, Kay Elemetrics Corp.). The CSL is an acoustic analysis system with robust hardware and contains software for a variety of speech/voice operations, such as signal acquisition, editing, analysis and interpretation. Participants were asked to sit upright in a chair, keeping their hips and knees at approximately 90° flexion. The chair was positioned three (3) feet away from the examiner; the participant was asked to speak as they "normally would to someone this far away in a room like this". Environmental noise levels in both testing sites were kept to a minimum. While both testing rooms were perceptually assessed to be very quiet by the examiners, only the testing room at the NIH was sound-treated. No actual measurement was made of the sound pressure levels of ambient noise in either testing area. Mouth-to-microphone distance was maintained at 12 cm at a 45° angle. For nasalance testing, the Nasometer™ (Model 6200-3, Kay Elemetrics Corp.) was used. Each participant was asked to wear a headset consisting of separate microphones for the oral and nasal cavities separated by a metal plate perpendicular to the facial plane.

Each participant was asked to perform three different tasks. These were first demonstrated by the investigators and the participants were given adequate time to practice each task prior to the recording. To obtain measures of fundamental frequency, vocal intensity, and perturbation (jitter and shimmer), subjects were instructed to sustain the vowel /a/ at a comfortable pitch and loudness for 8-10 seconds. They were then asked to speak spontaneously (e.g. to describe how they got to the testing venue) for one minute to assess speaking fundamental frequency and vocal intensity. Nasalance scores were then collected as they read sentences loaded with plosives (e.g., "put the puppy out," "*tapa at baboy*") and sentences dominated by sibilants (e.g., "I saw Susie at the seashore," "*sasakay ako sa kotse*"). Voice samples were analyzed using the Voicing Analysis Software (version 5.x) of the CSL. For sustained vowel phonation, the entire sample was used for analysis. Percent nasalance was obtained using the Nasometer™. Statistical analysis of the data was performed using R version 3.0.1.

Results and Discussion

The following acoustic voice measures were extracted: (1) mean fundamental frequency (F_0), (2) mean speaking fundamental frequency (SF_0), (3) speaking fundamental frequency range (SF_0 range), (3), (4) mean sound pressure level (SPL), (5) SPL range, (6) jitter percent (jitter %), (7) shimmer percent (shimmer %), and (8) percent nasalance. Table 2 summarizes the average values for these measures by gender. Tables 3, 4, and 5 show task-specific results. Table 6 provides a review of related studies, including a detailed description of the participants and the equipment/analysis software used. *"Table showing Acoustic Voice Measurements Obtained from Related Studies" can be found at <http://pjhrd.upm.edu.ph/index.php/main/article/view/190>.*

Table 2. *Acoustic voice measures obtained by gender*

Parameter	Male	Female	Test Statistic	P- value
Fundamental Frequency (in Hz)				
Fundamental frequency (F_0)	125.8 ±23.4	196.3 ±23.0	W = 4962	p < 0.001
Speaking fundamental frequency (SF_0)	122.6 ±15.6	194.8 ±19.0	W = 4913	p < 0.001
SF_0 Range	85.8 – 269.3	97.1 – 309.6		
Vocal intensity (in dB SPL)				
SPL, connected speech	58.6 ± 5.3	57.6 ± 4.3	W = 2112.5	p = 0.128
SPL, sustained vowel phonation	57.6 ±4.3	65.3 ±4.5	W = 2033.5	p = 0.048
Perturbation (in %)				
Jitter	0.92 ±0.48	1.12 ±0.34	W = 3169	p < 0.001
Shimmer	2.21 ±0.73	2.7 ±0.64	W = 3713	p < 0.001
Nasalance (in %)				
Sustained vowel phonation	17.1± 18.5	19.1 ±14.3	W = 317.5	p = 0.207
Plosive-dominant sentence	17.0 ± 11.6	13.2 ±7.45	W = 214.5	p = 0.319
Sibilant-dominant sentence	12.5 ±6.22	13.1 ±5.94	W = 276	p = 0.734

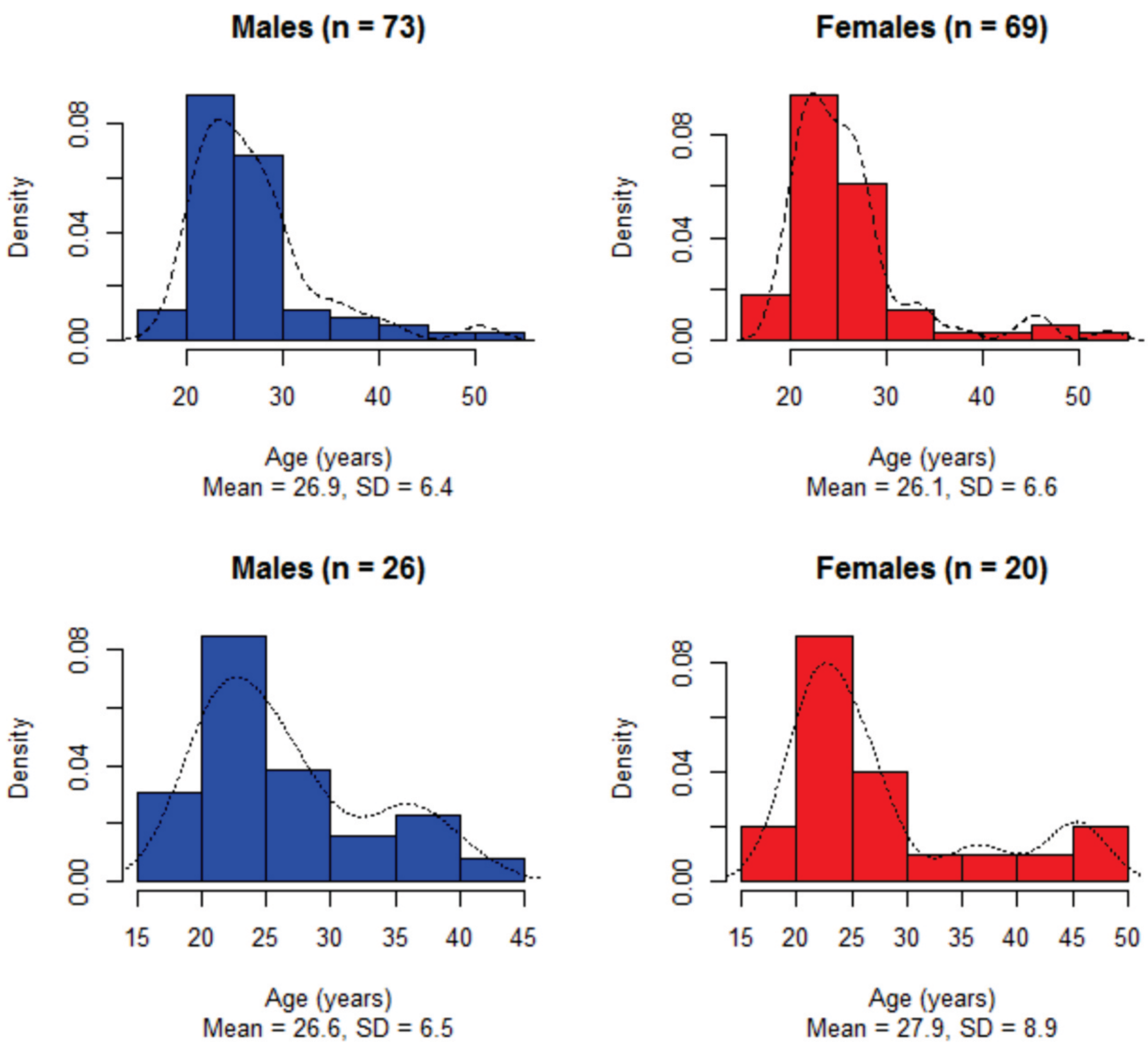

Figure 1. *Distribution of ages of the participants. The upper histograms show participants included in (a) voice testing, while the lower show those included in (b) nasalance testing.*

While 142 individuals agreed to participate in this study, nasalance was measured in only 46 due to limitations in equipment access and availability. Participant age was not a normally distributed variable as there were markedly more 20-30 year old participants than any other age group (Figure 1) hence, parametric testing would not have been appropriate. The Wilcoxon-Rank-Sum test was done to examine if there were significant differences between acoustic measures obtained from male and female speakers. An alpha level of 0.05 was selected as this was an exploratory study. P-values are summarized in Table 2. Although data are also presented for age groups ranging from 15-45 years old, age effects could not be reliably assessed because of inadequate sample size for age groups 30 to 50 years old.

Fundamental Frequency Measures (F_0, SF_0, and SF_0 Range)

The current study showed that the Filipino male participants exhibited a mean F_0, and mean Sf_0 of 125.8 (±23.4) Hz, 122.6 (±15.6) Hz, respectively. The range for mean F_0 in male speakers was 92.9-229.5 Hz and range for mean SF_0 was 98.8 - 173.9 Hz. The study found that Filipino men exhibited a higher SF_0 than North American [11,

Table 3. *Acoustic Voice Measures Obtained During Sustained Vowel Phonation*

Sustained Vowel Phonation (/a/)						
Age Group	**n**	**Mean Age**	**F_0 (Hz) Mean (SD)**	**SPL (dB) Mean (SD)**	**Jitter (%)**	**Shimmer (%)**
Females						
16 – 20	6	19.5	199.8 (25.6)	69.6 (5.7)	1.00 (0.29)	2.60 (0.06)
21 – 25	33	22.8	197.1(22.4)	65.2 (3.9)	1.07 (0.23)	2.88 (0.75)
26 – 30	21	27.3	194.0 (27.3)	62.5 (3.4)	1.28 (0.48)	2.57 (0.62)
31 – 35	4	33.5	192.6 (10.1)	68.2 (2.4)	1.09 (0.19)	2.66 (0.10)
36 – 40	1	38.0	213.2	73.4	1.03	2.92
41 – 45	1	44.0	195.8	63.1	0.84	2.59
46 – 50	2	46.0	206.1	71.0 (3.0)	0.83	2.65 (0.04)
51 – 55	1	53.0	178.6	67.4	1.12	2.51
TOTAL	69	26.1	196.3 (23.0)	65.3 (4.5)	1.12 (0.34)	2.7 (0.64)
Males						
16 – 20	4	19.5	123.4 (24.9)	65.2 (4.0)	0.87 (0.23)	2.02 (0.60)
21 – 25	33	22.9	126.4 (24.0)	66.1 (7.2)	0.81 (0.26)	2.34 (0.76)
26 – 30	25	28.1	128.0 (25.6)	66.0 (5.2)	1.08 (0.73)	2.24 (0.75)
31 – 35	4	34.3	124.2 (18.5)	70.6 (3.8)	1.05 (0.28)	2.12 (0.10)
36 – 40	3	37.3	123.7 (14.8)	71.1 (3.2)	0.82 (0.13)	2.11 (0.24)
41 – 45	2	41.0	101.5	66.5	0.98	1.61
46 – 50	0					
51 – 55	2	50.5	123.6	72.4	0.87	1.1
TOTAL	73	26.9	125.8 (23.4)	66.6 (6.2)	0.92 (0.48)	2.21 (0.73)

Table 4. *Acoustic Voice Measures Obtained During Spontaneous Speech Tasks*

Spontaneous Speech						
Age Group	**n**	**Mean Age**	**SF_0 (Hz)**		**SPL (dB)**	
			Mean (SD)	**SF_0 Range**	**Mean (SD)**	**SPL Range**
Females						
16 – 20	6	19.5	200.7 (20.5)	168.8 – 224.5	59.9 (4.4)	52.9 – 65.7
21 – 25	33	22.8	197.4 (14.6)	168.6 – 224.8	58.3 (3.5)	51.5 – 64.8
26 – 30	21	27.3	187.9 (25.6)	99.1 – 220.5	54.3 (2.9)	45.8 – 58.8
31 – 35	4	33.5	205.0 (11.4)	196.3 – 220.9	63.6 (4.1)	60.5 – 69.4
36 – 40	1	38.0	202.2	202.2	67.22	67.22
41 – 45	1	44.0	191.0	191.0	56.4	56.4
46 – 50	2	46.0	185.6	181.4 – 189.7	56.9	55.2 – 58.6
51 – 55	1	53.0	195.8	195.8	60.8	60.8
TOTAL	69	26.1	194.8 (19.0)	99.1 – 224.8	57.6 (4.3)	45.8 – 69.4
Males						
16 – 20	4	19.5	126.9 (32.4)	90.8 – 319.5	57.3 (4.5)	51.1 – 61.8
21 – 25	33	22.9	123.8 (14.5)	86.4 – 267.8	60.1 (6.3)	54.0 – 90.2
26 – 30	25	28.1	122.3 (16.0)	84.7 – 274.8	56.4 (4.0)	49.9 – 64.1
31 – 35	4	34.3	122.8 (11.8)	81.3 – 269.3	59.7 (3.0)	56.2 – 61.7
36 – 40	3	37.3	117.6 (12.6)	91.3 – 211.0	58.6 (2.7)	55.6 – 61.1
41 – 45	2	41.0	108.0	79.5 – 275.5	57.6	53.5 – 61.7
46 – 50	0					
51 – 55	2	50.5	117.3	88.0 – 229.0	61.2	59.6 – 62.7
TOTAL	73	26.9	122.6 (15.6)	85.8 – 269.3	58.6 (5.3)	49.9 – 90.2

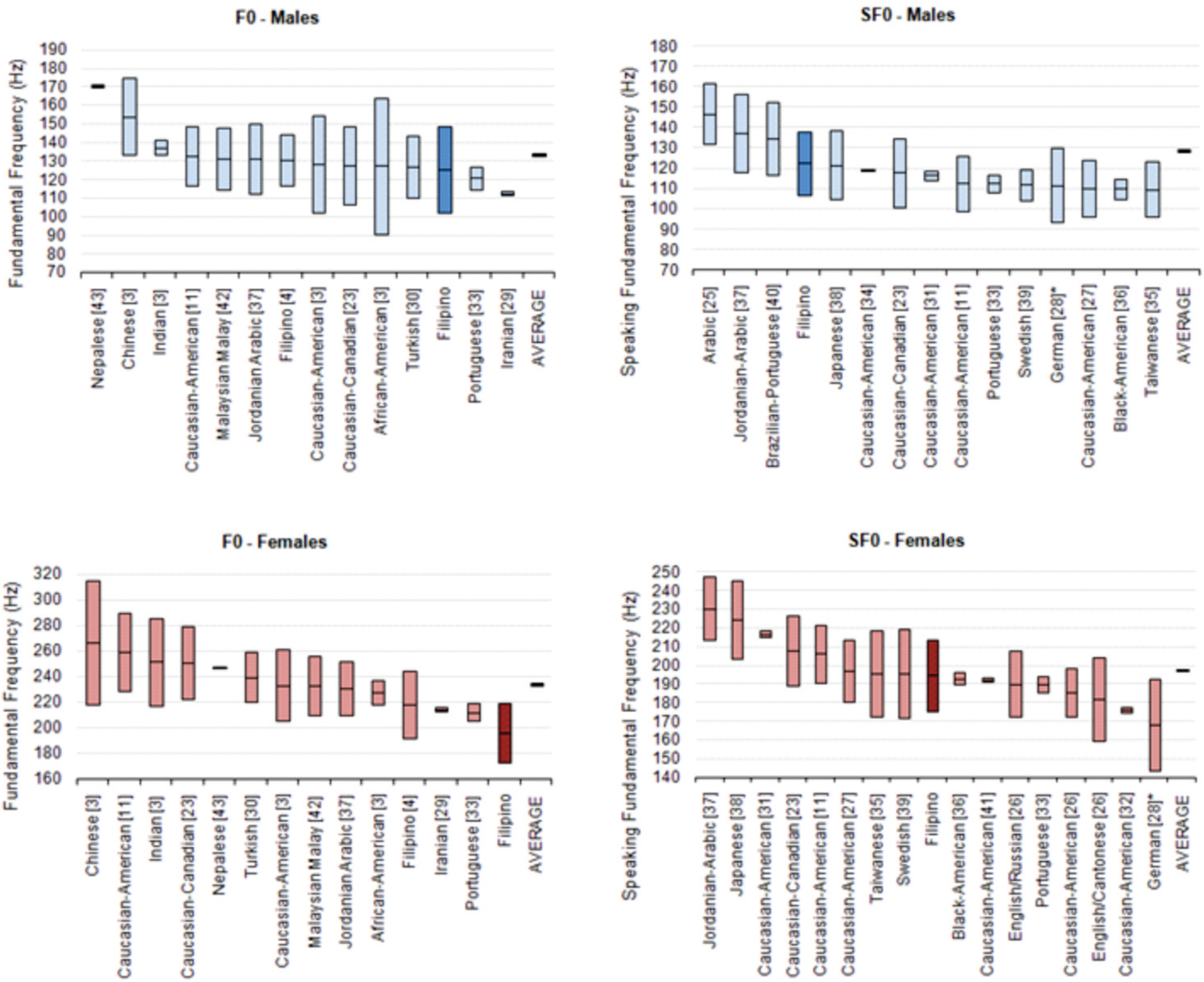

Figure 2. *Average Fundamental Frequency (F_0) and Speaking Fundamental Frequency (SF_0) of Male and Female Speakers Reported in This and in Various Studies. F_0 values across several studies were obtained during sustained phonation for males (a) and females (c). SF_0 values are shown in (b) and (d). Upper and lower bars represent +1SD and -1SD from the mean. Data from the current study appear as darker shades of blue (for males) and red (for females). Average values for all related studies are also included in each graph for comparison.*

**-data obtained mostly from subjects > 50 years old*

23,27,31,34,36], Portuguese [33], Swedish [39], Taiwanese [35], and Japanese [38] speakers, but a lower SF_0 than Arabic [25,37] and Brazilian subjects. In terms of F_0, the subjects demonstrated slightly lower mean values than those obtained by Delovino *et al.* [4] at 131 (±14) Hz for 28 Filipinos aged 22-43 years. Mean F_0 values were likewise markedly lower than those for Chinese [3], Indian [3], and Nepalese [43] speakers. It would appear that the fundamental frequency for both isolated vowel production and for continuous speech of Filipino men is fairly similar to that of male speakers from other countries and/or heritage backgrounds (F_0 = 132.8 Hz, SF_0 = 118.4 Hz).

By comparison, it would appear that mean fundamental frequency for Filipinas (female Filipinos) is slightly lower than that of others. Female participants in this study exhibited a mean F_0 of 196.3 Hz (±23.0) and mean SF_0 of 194.8 Hz (±19.0), with a mean SF_0 range of 97-310 Hz. The range for mean F_0 in females was 141.4 – 251.6 Hz and range for mean SF_0 was 99.1 – 224.8 Hz. The 18-27 year old females in Goy *et al.* [20] yielded a mean F_0 of 251 (±28) Hz and a mean SF_0 of 208 (±19) Hz. Filipinas in this study had lower SF_0 compared to Arabic [37], North American [11,23,27,31], Swedish [39], Taiwanese [35], Japanese [38], but higher than those for other American [32,36,41], English-Cantonese bilinguals [26], and other European [28,33] speakers. While SF_0 appeared to be consistent with the average SF_0 values across other studies (197 Hz), a distinctly lower mean F_0 was observed. Similarly, Delovino *et al.* [4] also documented a mean F_0 of 218.4 Hz among the 28 Filipinas aged 20-45 year old.

Figure 2 summarizes the fundamental frequency data from other studies. The contrast between findings of this study and most other studies, including that of Delovino *et al.* [4] who also documented voice functions in Filipina speakers, would appear to indicate an artifact of data collection in our study, such as perhaps the very quiet and calm speech sampling conditions. That male speakers in this study did not vary greatly in fundamental frequency from other studies contradicts that, however. It would appear that additional data to confirm these findings would be useful. F_0 values for women may have been also affected by the type of instruction and model provided for the sustained vowel task. Despite this, and consistent with the studies cited above, the female participants in this study also exhibited significantly higher F_0 and SF_0 values than the male participants (W = 4962, $p < 0.001$; W = 4913, $p < 0.001$).

3.2 Sound Pressure Level (SPL)

On the average, male participants spoke with an intensity level of 58.6 (±5.3) dB but appeared to use a louder intensity level of 66.6 (±6.2) dB during sustained phonation of a vowel (Table 3). Similarly, female participants had an SPL of 57.6 (±4.3) dB when speaking and 65.3 (±4.5) dB when sustaining a vowel (Table 4). Male and female speakers had a marginal but statistically significant difference in vocal intensity during sustained phonation (W = 2033.5, p = 0.048) but not during connected speech (W = 2112.5, p = 0.128). While statistically significant, an average difference of 1.0 to 1.3 dB did not appear to be clinically significant.

The mean SPL of 58-59 dB used by our Filipino participants during conversation appears similar to those reported by Berg *et al.* [28] for 40-49 year old Germans (58.8-59.9 dB). The mean vocal intensity obtained during sustained vowel phonation (65-66 dB) was higher than what Brown *et al.* reported for American women (63.3 dB) [44], but lower than those in Goy *et al.* (67.8-69.7 dB, Canadian) [6], Hwa Chen (69.6-70.8 dB, Taiwanese) [35], Demirhan (70-71.5 dB, Turkish) [30], and Gelfer and Young (68.2-70.4 dB, American) [45]. Higher SPL levels were associated with increasing age of participants [28] as well while language-related variables (e.g. tonal effects of Mandarin) [35]. These, as well as other factors, such as speaking distance, room acoustics, speaking distance, as well as the inherent differences in intensity among phonemes, are hypothesized to influence the results. It is highly likely the participants in this study adjusted their loudness to what they felt was appropriate for a conversation with a nearby listener in a quiet environment. Their loudness levels for this study may be lower than the typical vocal intensity during conversation among Filipinos as, anecdotally, the typical ambient noise levels in the working and living environments are relatively higher compared to experimental conditions.

Jitter (%) and Shimmer (%)

Male participants exhibited a jitter of 0.92 % (±0.48) and a shimmer of 2.21 % (±0.73) while female participants generated a higher jitter at 1.12 % (±0.34) as well as a shimmer at 2.7 % (±0.64). The female subjects in this study exhibited significantly higher jitter % (W = 3169, $p< 0.001$) and shimmer % (W = 3713, $p< 0.001$) values than their male counterparts. This gender effect was also observed among Turkish [30], Swiss [46], and Filipino subjects [4]. Filipino

Table 5. *Nasalance Scores for Male and Female Filipinos during Sustained Vowel Phonation and Oral Reading (n=46)*

Speech Task	Male		Female		All	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
Vowel Prolongation	17.14 (18.52)	2.71-88.86	19.05 (14.25)	4.07-60.46	17.97 (16.65)	2.71-88.86
Dominantly plosive sentence	16.97 (11.64)	3.94-56.81	13.19 (7.45)	4.04-35.76	15.33 (10.11)	3.94-56.81
Dominantly sibilant sentence	12.53 (6.22)	0.40-26.45	13.10 (5.94)	5.54-25.72	12.78 (6.04)	0.40-26.45

jitter % was also higher than those reported in studies that looked into jitter% and shimmer% [4,23,30,43,46]. Shimmer% indicated normal amplitude perturbation as it is lower than the 3.81% threshold for CSL-obtained samples. However, it may initially appear that Filipina subjects had pathologic voices as they exhibited jitter % above than the 1.04% threshold. However, this study hypothesized that several other factors may explain this finding as well as the discrepancies noted with other studies. First, a dynamic microphone placed at a distance of 12 cm and oriented at a 45 degree angle was used. Titze and Winholtz [47] found that cardioid condenser types placed at shorter distances produced better perturbation data than dynamic ones. Second, voice samples were collected during sustained /a/ phonation at an intensity between 55-60 dB. Vocal loudness was found to be the most influential factor in perturbation measurements and it was recommended to be maintained at 75 to 80 dB during sampling to enhance measurement reliability [46,48]. Lastly, the CSL was used which employs a peak-picking method for glottal pulse detection. Reliable perturbation measurements depend on accurate extraction of F_0 and amplitude of various waveform types [49]. Unfortunately, peak-picking method was found to be less sensitive to additive noise as opposed to waveform-matching, resulting in less accurate jitter measurements [49,50]. Future studies may need to control the said parameters to maintain more robust findings.

Nasalance

Percent nasalance was measured using three different speech tasks in which low nasality is expected. Average nasalance when reading sibilant-loaded passages was 12.5±6.22% for males and 13.1 ± 5.94% for females. When reading plosive-loaded passages, males exhibited a mean nasalance score of 16.9 ± 11.6% while females at 13.2±7.5%. Higher nasalance scores were obtained from sustained vowel phonation: 17.14% (±18.5) for male participants and 19.1%(±14.3) for female participants. Nasalance scores of male speakers were not significantly different from those of female speakers in all three tasks: sustained phonation ($W = 317.5$, $p = 0.207$), plosive-dominant sentences ($W = 214.5$, $p = 0.319$), sibilant-dominant sentences and ($W = 276$, $p = 0.734$). However, one study by Van Lierde *et al*. [52] found gender-related differences in nasalance as a function of velopharyngeal valving and vocal tract length.

Mean nasalance values of Filipinos from this study appear to be similar to participants of other ethnic backgrounds, especially for Malaysian (13.9 ± 5.11) [53], Thai (14.3 ± 5.8) [58], American (16.0 ± 7.0) [51] and Greek (12.4 ± 4.8) [59]. However, due to the wide variance observed in the data, it is quite difficult to make definite conclusions regarding ethnolinguistic differences or similarities. This study did not ensure a fixed oral-to-nasal consonant ratio between sentences used that may prove to be a possible source of variance.

Possible Age-Related Differences

While the current study did not aim to investigate acoustic voice changes across the lifespan, initial observations were documented. Statistical analysis would be inappropriate at this point due to reduced variance and covariance especially in the older age groups. Testing for differences between the 20-25 and the 25-30 year old group would be possible, but few changes would be expected within a 10-year period and may not be useful clinically.

Figure 3 summarizes trends observed across different acoustic parameters. Fundamental frequency measures (F_0 and SF_0) appear to slightly decrease with age. There also appears to be a downward trend for frequency and intensity ranges. Older male participants exhibited increased jitter % and decreased shimmer %. Nasalance scores also appear to increase with age for both age groups. However, these measures may not necessarily follow a linear model and need to be investigated further. In their lifespan investigation of acoustic voice characteristics of 192 North American subjects aged between 4 to 93 years, Stathopoulos and his colleagues demonstrated that voice changes followed a non-linear, U-shaped curve [18]. These changes often reflect changes in laryngeal structure (e.g., vocal fold tissue elasticity, laryngeal position), physiological mechanisms, and motor control.

Conclusion

This study aimed to describe the vocal characteristics of a sample of Filipinos with perceptually normal voices. Voice samples were collected from 142 subjects during sustained vowel /a/ phonation and spontaneous speech. The Computerized Speech Laboratory (CSL) Model 4300B was used to extract fundamental frequency, sound pressure level, and perturbation measures. Nasalance scores were obtained from sustained /a/ phonation and oral reading of sibilant-loaded and plosive-loaded passages, then analyzed using the Nasometer™ 6200-3.

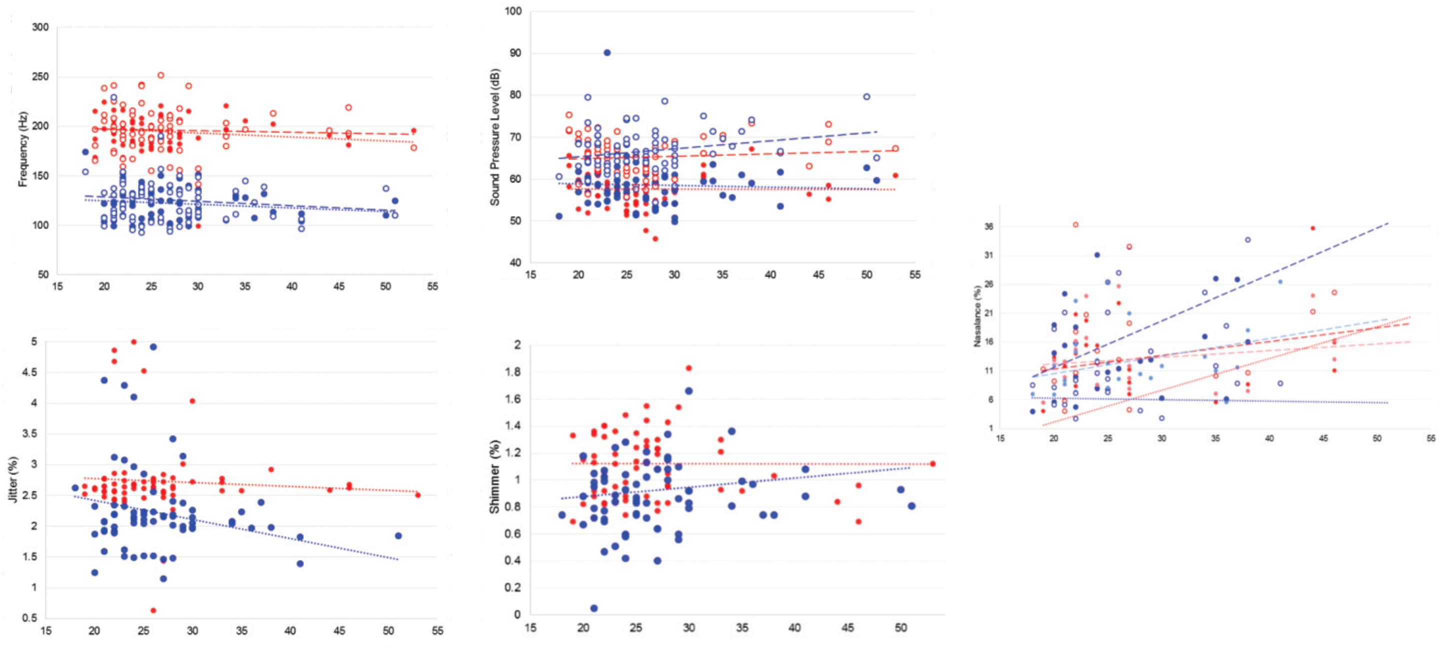

Figure 3. *Changes in fundamental frequency (Hz), intensity (SPL), and perturbation values (%) with age (years). Blue circles refer to male subjects; red circles to female subjects. Upper graphs show F_0 and SPL values during sustained phonation (unfilled circles) and spontaneous speech (filled circles). Scatter plot for nasalance include values in different tasks—reading aloud plosive-loaded sentences (filled circles), sibilant-loaded sentences (filled, light-colored circles), and sustained vowel phonation (unfilled circles). Linear regression lines are shown as dotted lines.*

The average acoustic values for males were a fundamental frequency (F^0) during sustained phonation of 125.8 ± 23.4 Hz, a fundamental frequency during spontaneous speech (SF_0) of 122.6 ± 15.6 Hz, and a pitch range of 85.8 – 269. The average loudness levels sound pressure levels (SPL) for male speakers was 58.6 ± 5.3 dB during speech, and 66.6 ± 6.2 dB during sustained vowel production. Average jitter for male speakers was 0.92 ± 0.48%, average shimmer was 2.21% ± 0.73%. Average nasalance for male speakers was 12.5-17.1%.

The average acoustic values for females were F_0 of 196.3 with a standard deviation of ± 23.0 Hz, an SF_0 of 194.8 ± 19.0 Hz; pitch range during conversation speech was 97.1 - 309.6Hz. The average loudness or SPL of female speakers during conversational speech was 57.6 ± 4.3 dB, and SPL during sustained vowel production was 65.3 ± 4.5 dB. Average jitter was 1.12% with a standard deviation of ± 0.34%, average shimmer was 2.7% ± 0.64%, and nasalance was 13.1-19.1%.

Gender effects were seen only for perturbation measures and fundamental frequency values, with females exhibiting higher values. Possible age-related effects were also suggested. Comparing data from those obtained in related studies, it would appear that Filipino subjects exhibit lower F_0 and SPL values, higher jitter%, and SF_0 and shimmer% values that are fairly similar to the average values reported across studies.

Overall, this study presented data that may be used together with the data from Delovino *et al.* (2012) to form initial normative data pertinent to Filipino vocal performance. The reliability of future studies can be enhanced by controlling extraneous variables that affect sampling and acoustic analysis. These include employing stricter eligibility criteria (e.g., larger sample, controlling for medical history, hearing screening, professional voice training, perceptual evaluation), improving voice data acquisition (e.g., standardized instructions to the subject, inter-rater reliability among data collectors, exclusion of the first and last segments of each voice sample for analysis, etc.), and more robust data analysis (e.g. using different analysis programs, inclusion of other perturbation measures, HNR, data stratification according to age, gender, and software). Finally, future investigations should also consider the possible effects of dialectic variation.

Acknowledgement

This study was funded by a grant from the University of the Philippines Manila National Institutes of Health (NIH-0797). We would like to acknowledge the contributions of

Ma. Avelina B. Gallardo, Czarina Catherine B. Maximo, Aimee Gene E. Reyes, Marcus Reiner T. Roldan, Nadine Joy M. Sy, Amihan B. Tayag, Johncy Rose Concepcion, Amado G. Torres and Kathlyn B. Crisostomo especially in the collection of data for this study.

References

1. Rabinov CR, Kreiman J, Gerratt BR, Bielamowicz S. Comparing reliability of perceptual ratings of roughness and acoustic measures of jitter. Journal of Speech and Hearing Research, 1995;38:26-32.
2. Aronson A. Clinical Voice Disorders: An Interdisciplinary Approach (2nd ed.). USA: Thieme Inc. 1995.
3. Andrianopoulos MV, Darrow KN, Chen J. Multimodal standardization of voice among four multicultural populations: fundamental frequency and spectral characteristics. Journal of Voice, 2001;15:194-219. doi: 10.1016/S0892-1997(01)00021-2
4. Delovino KAE, Casile R, Hawson FY. Vocal acoustic measures of asymptomatic Filipino young adults at a private tertiary hospital in Quezon City – a pilot study. Philippine Journal of Otolaryngology-Head and Neck Surgery, 2012;27(2):7–11.
5. Britto A, Doyle P. A comparison of habitual and derived optimal voice fundamental frequency values in normal young adult speakers. Journal of Speech and Hearing Disorders, 1990;55:476-484.
6. Gelfer M. Fundamental frequency, intensity, and vowel selection: effects on measures of phonatory stability. Journal of Speech and Hearing Research, 1995;38:1189-1198.
7. Hollien H, Shipp T. Speaking fundamental frequency and chronological age in males. Journal of Speech and Hearing Research, 1972;15:155-159. doi:10.1044/jshr.1501.155
8. Horii Y. Vocal shimmer in sustained phonation. Journal of Speech and Hearing Research, 1980;23:202-209. doi:10.1044/jshr.2301.202
9. Stoicheff M. Speaking fundamental frequency characteristics of non-smoking female adults. Journal of Speech and Hearing Research, 1981;24:437-441. doi:10.1044/jshr.2403.437
10. Holmberg EB, Hillman RE, Perkell JS, Gress C. Relationships between intra-speaker variation in aerodynamic measures of voice production and variation in SPL across repeated recordings. Journal of Speech and Hearing Research, 1994;37:484-495. doi:10.1044/jshr.3703.484
11. Fitch J. Consistency of fundamental frequency and perturbation in repeated phonations of sustained vowels, reading and connected speech. Journal of Speech and Hearing Disorders, 1990;55:360-363.
12. Walton JH, Orlikoff RF. Speaker race identification from acoustic cues in the vocal signal. Journal of Speech and Hearing Research, 1994;37:738-745. doi:10.1044/jshr.3704.738
13. Higgins M, Saxman, J. A comparison of selected phonatory behaviors of healthy aged and young adults. Journal of Speech and Hearing Research, 1991;34:1000-1010. doi:10.1044/jshr.3405.1000
14. Bielamowicz S, Kreiman J, Gerratt BR, Dauer MS, Berke GS. Comparison of voice analysis systems for perturbation measurement. Journal of Speech and Hearing Research, 1996;39:126-134. doi:10.1044/jshr.3901.126
15. De Krom G. Consistency and reliability of voice quality ratings for different types of speech fragments. Journal of Speech and Hearing Research, 1994;31:485-490. doi:10.1044/jshr.3705.985
16. Deliyski D, Shaw H, Evans M, Vesselinov R. Regression tree approach to studying factors influencing acoustic voice analysis. Folia Phoniatrica Et Logopaedica, 2006;58(4):274-288. http://dx.doi.org/10.1159/000093184
17. Maryn Y, Corthals P, De Bodt M, Van Cauwenberge P, Deliyski D. Perturbation measures of voice: a comparative study between Multi-Dimensional Voice Program and Praat. Folia Phoniatrica Et Logopaedica, 2009;61(4):217-226. http://dx.doi.org/10.1159/000227999
18. Prater R, Swift R. Manual of voice therapy (1st ed.). Austin, Tex.: PRO-ED. 1990.
19. Colton RH, Casper JK, Leonard R. Differential diagnosis of voice problems. Understanding voice problems: a physiological perspective for diagnosis and treatment (4th ed., pp. 11-62). Philadelphia: Lippincott Williams & Wilkins. 2011.
20. Finnegan E, Luschei E, Hoffman H. Modulations in respiratory and laryngeal activity associated with changes in vocal intensity during speech. Journal Of Speech Language And Hearing Research, 2000;43(4):934. http://dx.doi.org/10.1044/jslhr.4304.934
21. Stathopoulos ET, Huber JE, Sussmana JE. Changes in acoustic characteristics of the voice across the life span: measures from individuals 4–93 years of age. Journal of Speech, Language, and Hearing Research, 2011;54:1011-1021. doi: 10.1044/1092-4388(2010/10-0036)
22. Aronson AE, Bless DM. Clinical voice disorders. (4th ed., p. 146). New York: Thieme. 2009

23. Goy H, Fernandes DN, Pichora-Fuller MK, van Lieshout P. Normative voice data for younger and older adults. Journal of Voice, 2013;27(5):545-555.
24. Lee G, Wang C, Fu S. Evaluation of hypernasality in vowels using voice low tone to high tone ratio. Cleft Palate–Craniofacial Journal, 2009;46(1):1. doi: 10.1597/07-184.1
25. Abu-Al-Makarem A, Petrosino L. Reading and spontaneous speaking fundamental frequency of young Arabic men for Arabic and English languages: a comparative study. Perceptual And Motor Skills, 2007;105(2):572-580. http://dx.doi.org/10.2466/pms.105.2.572-580
26. Altenberg E, Ferrand C. Fundamental frequency in monolingual English, bilingual English/Russian, and bilingual English/Cantonese young adult women. Journal Of Voice, 2006;20(1):89-96. http://dx.doi.org/10.1016/j.jvoice.2005.01.005
27. Benjamin B. Frequency variability in the aged voice. Journal Of Gerontology, 1981;36(6):722-726. http://dx.doi.org/10.1093/geronj/36.6.722
28. Berg M, Fuchs M, Wirkner K, Loeffler M, Engel C, Berger T. The speaking voice in the general population: normative data and associations to sociodemographic and lifestyle factors. Journal Of Voice, 2017;31(2):257.e13-257.e24. http://dx.doi.org/10.1016/j.jvoice.2016.06.001
29. Dehqan A, Ansari H, Bakhtiar M. Objective voice analysis of Iranian speakers with normal voices. Journal Of Voice, 2010;24(2):161-167. http://dx.doi.org/10.1016/j.jvoice.2008.07.005
30. Demirhan E, Unsal E, Yilmaz C, Ertan E. Acoustic voice analysis of young Turkish speakers. Journal Of Voice, 2016;30(3):378.e21-378.e25. http://dx.doi.org/10.1016/j.jvoice.2015.04.018
31. Fitch J, Holbrook A. Modal vocal fundamental frequency of young adults. Archives Of Otolaryngology - Head And Neck Surgery, 1970;92(4):379-382. http://dx.doi.org/10.1001/archotol.1970.04310040067012
32. Gilbert H, Weismer G. The effects of smoking on the speaking fundamental frequency of adult women. Journal Of Psycholinguistic Research, 1974;3(3): 225-231. http://dx.doi.org/10.1007/bf01069239
33. Guimarães I, Abberton E. Fundamental frequency in speakers of Portuguese for different voice samples. Journal Of Voice, 2005;19(4):592-606. http://dx.doi.org/10.1016/j.jvoice.2004.11.004
34. Hollien H, Shipp T. Speaking fundamental frequency and chronologic age in males. Journal Of Speech Language And Hearing Research, 1972;15(1):155. http://dx.doi.org/10.1044/jshr.1501.155
35. Hwa Chen S. Sex differences in frequency and intensity in reading and voice range profiles for Taiwanese adult speakers. Folia Phoniatrica Et Logopaedica, 2007:59(1):1-9. http://dx.doi.org/10.1159/000096545
36. Hudson A. Holbrook A. A study of the reading fundamental frequency of young black adults. Journal of Speech and Hearing Research, 1981;24: 197-201. doi:10.1044/jshr.2402.197
37. Natour Y, Wingate J. Fundamental frequency characteristics of Jordanian Arabic speakers. Journal Of Voice, 2009;23(5):560-566. http://dx.doi.org/10.1016/j.jvoice.2008.01.005
38. Nishio M, Niimi S. Changes in speaking fundamental frequency characteristics with aging. Folia Phoniatrica Et Logopaedica, 2008;60(3):120-127. http://dx.doi.org/10.1159/000118510
39. Pegoraro-Krook, M. Speaking fundamental frequency characteristics of normal Swedish subjects obtained by glottal frequency analysis. Folia Phoniatrica Et Logopaedica, 1988;40(2):82-90. http://dx.doi.org/10.1159/000265888
40. Pegoraro-Krook M, Castro V. Normative speaking fundamental frequency (SFF) characteristics of Brazilian male subjects. Braz J Med Biol Res, 1994;27(7):1659-61.
41. Saxman J, Burk K. Speaking Fundamental Frequency Characteristics of Middle-Aged Females. Folia Phoniatrica Et Logopaedica, 1967;19(3):167-172. http://dx.doi.org/10.1159/000263141
42. Ting H, Chia S, Abdul Hamid B, Mukari S. Acoustic Characteristics of Vowels by Normal Malaysian Malay Young Adults. Journal Of Voice, 2011;25(6):e305-e309. http://dx.doi.org/10.1016/j.jvoice.2010.05.007
43. Toran K, Lal B. Objective analysis of voice in normal young adults. Kathmandu University Medical Journal, 2010;7(4). http://dx.doi.org/10.3126/kumj.v7i4.2757
44. Brown W, Morris R, Hicks D, Howell E. Phonational profiles of female professional singers and nonsingers. Journal Of Voice, 1993;7(3):219-226. http://dx.doi.org/10.1016/s0892-1997(05)80330-3.
45. Gelfer MP, Young SR. Comparisons of intensity measures and their stability in male and female speakers. Journal of Voice, 1997;11(2):178-186. http://dx.doi.org/10.1016/S0892-1997(97)80076-8
46. Brockmann M, Storck C, Carding PN, Drinnan MJ. Voice loudness and gender effects on jitter and shimmer in healthy adults. Journal of Speech,

Language, and Hearing Research, 2008;51:1152-1160. doi:10.1044/1092-4388(2008/06-0208)

47. Titze I, Winholtz W. Effect of microphone type and placement on voice perturbation measurements. Journal of Speech, Language, and Hearing Research, 1993;36:1177-1190. doi:10.1044/jshr.3606.1177
48. Leong K, Hawkshaw MJ, Dentchev D, Gupta R, Lurie D, Sataloff RT. Reliability of objective voice measures or normal speaking voices. Journal of Voice, 2013;27:170-176. http://dx.doi.org/10.1016/j.jvoice.2012.07.005
49. Titze I, Liang H. Comparison of Fo extraction methods for high-precision voice perturbation measurements. Journal of Speech, Language, and Hearing Research, 1993;35:1120-1133. doi:10.1044/jshr.3606.1120
50. Boersma P. Should jitter be measured by peak picking or by waveform matching? Folia Phoniatr Logop, 2009;61:305–308.
51. Seaver E, Dalston R, Leeper H, Adams L. A study of nasometric values for normal nasal resonance. Journal Of Speech Language And Hearing Research, 1991;34(4):715. http://dx.doi.org/10.1044/jshr.3404.715
52. Van Lierde KM, *et al.* Nasometric values for normal nasal resonance in the speech of young Flemish adults. Cleft Palate–Craniofacial Journal, 2001;38(2),:112-118.
53. Ibrahim H, Reilly S, Kilpatrick N. Normative Nasalance Scores for the Malay Language. The Cleft Palate-Craniofacial Journal, 2012;49(5):e61-e63. http://dx.doi.org/10.1597/11-001
54. Ha-Kyung Kim, Xiao-meng Yu, Yan-jing Cao, Xiao-ming Liu, Zhao-Ming Huang. Dialectal and gender differences in nasalance for a Mandarin population, Clinical Linguistics & Phonetics, 2016;30:2:119-130, DOI: 10.3109/02699206.2015.1116111
55. Whitehill TL. Nasalance measures in Cantonese-speaking women. Cleft Palate–Craniofacial Journal, 2001;38(2):119-125. http://dx.doi.org/10.1597/1545-1569(2001)038<0119:NMICSW>2.0.CO;2
56. Mishima K, Sugii A, Yamada T, Imura H, Sugahara T. Dialectal and gender differences in nasalance scores in a Japanese population. Journal of Cranio-Maxillofacial Surgery, 2008;36:8-10. doi: 10.1016/j.jcms.2007.07.008
57. Lee A, Browne U. Nasalance scores for typical Irish English-speaking adults. Logopedics Phoniatrics Vocology, 2012;38(4):167-172. http://dx.doi.org/10.3109/14015439.2012.679965
58. Prathanee B, Thanaviratananich S, Pongjunyakul A, Rengpatanakij K. Nasalance scores for speech in normal Thai children. Scandinavian Journal of Plastic and Reconstructive and Hand Surgery, 2003;37:351-355
59. Okalidou A, Karathanasi A, Grigoraki E. Nasalance norms in Greek adults. Clinical Linguistics & Phonetics, 2011;25(8): 671-688. http://dx.doi.org/10.3109/02699206.2010.549993