Voice Range Profiles for Tonal Dialect of Min

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Key Words

Voice range profile · Min · Maximum range of vowel frequency change · Dynamic intensity range

Abstract

The influence of frequency and intensity in Min dialect on maximum vocal performance has not been investigated. The purposes of this study are (1) to investigate the physiological frequency and intensity ranges of the tonal dialect of Min, and (2) to compare the physiological frequency and intensity ranges of Min to those of nontonal languages. The subjects were 40 normal Taiwanese adults. All subjects were native Min speakers. The lowest frequency, the highest frequency, the maximum range of vowel frequency change (MRVFC), soft voice, loud voice, and the dynamic intensity range were obtained from voice range profiles. The independent t test was used to find the statistical significance of all frequency and intensity variables between female and male speakers in vocal range profiles. The results revealed that female speakers had significantly greater lowest frequency and highest frequency than male speakers. Male speakers had a significantly greater MRVFC than female speakers. Moreover, Min speakers had a greater MRVFC and dynamic intensity range than most of nontonal language speakers. The data provide an assessment tool of vocal function for Min speakers.

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Introduction

The important parameters of good voice are adequate voice quality, timbre, vocal fold adduction, respiratory support, perturbation, modulation, and frequency and intensity control [1]. Persons with voice disorders frequently have impairments in these parameters and therefore deteriorated vocal function. Improvement of vocal fold adduction and respiratory support in voice treatment and vocal training can expand frequency and intensity ranges, which thus increase the flexibility of speech and decrease speaking effort [2–5].

Several studies have provided evidence of vocal training and voice therapy effects on frequency and intensity ranges. Trained singers had significantly greater physiological frequency range and physiological intensity range than untrained subjects [6–11]. Similar effects were found in patients with voice disorders after voice therapy [2, 12, 13]. Awan [14] further proposed significant correlations between the physiological frequency range and speaking frequency range, and between the physiological intensity range and speaking intensity range in trained and untrained subjects. Awan's [14] findings indicated that an increased physiological frequency range may result from a large speaking frequency range in speech, and an increased physiological intensity range may result from a large speaking frequency range.

If the speaking frequency and speaking intensity ranges of a dialect are large enough to cause changes in phys-

iological frequency and physiological intensity ranges, everyday conversation of this dialect can be regarded as vocal training in frequency and intensity, which provides an inherent opportunity to enhance maximum vocal performance in frequency and intensity.

Min is a tonal language of Chinese and one of the major dialects in Taiwan. About 70% of the population are native Min speakers [15]. Min contains seven basic tones: high, rising, high falling, low falling, mid high, low short, and high short tones. Each word has one tone. Syllables with different tones convey different meanings [16, 17]. The range of fundamental frequency and intensity used in speaking Min mainly depends upon the high-low tone combination [3, 7, 18, 19]. Chen [20] proposed that the speaking frequency and speaking intensity ranges for Min speakers were greater than those in other studies for American English speakers [20]. Everyday conversation of Min dialect may provide a greater chance of vocal training on frequency and intensity which may result in greater physiological frequency and physiological intensity ranges for Min speakers than for nontonal language speakers. Current theory of maximum vocal performance in frequency and intensity is mainly on data derived from nontonal language speakers [7–10, 21, 22]. Because physiological frequency and physiological intensity ranges are important indicators of vocal training and voice therapy effects for singers and voice-disordered patients, it is important to establish reference data of maximum vocal performance in frequency and intensity for speakers of tonal dialect of Min.

The purposes of this study are (1) to investigate the physiological frequency and intensity ranges of the tonal dialect of Min in both genders and (2) to compare the physiological frequency and intensity ranges of the tonal dialect of Min to those of nontonal languages.

Material and Methods

Subjects

The research subjects for this study were 40 normal Taiwanese young adults of whom 20 were female and 20 were male. All subjects were native Min speakers who spoke Min as their mother tongue and spoke Min for over 80% of their daily conversation. Those speakers also spoke Mandarin, which was less than 20% of their daily conversation. The mean age of the research subjects was 25.4 years with an age range of 21–29 years.

All subjects were employees of Veterans General Hospital and students of Yang-Ming University in Taipei. The investigator of this study interviewed and evaluated the subjects on the day of the study. The selection criteria for the subjects were: (1) no history of smoking, heavy drinking, laryngeal surgery, vocal fold pathology,

throat problems, hearing impairment, respiratory problems, neurological problems, or singing training; (2) normal voice as judged through perceptual evaluation and videostroboscopic examination, and (3) native Min speakers.

Determination of Frequency and Intensity Data in Voice Range Profiles

For each subject, a frequency intensity profile was obtained using a Phonetogram (Kay, model 4326), a module of the Computer Speech Lab (CSL, Kay, model 4300). A condenser microphone (AKG 410) was connected to a Stewart Electronics 48V Phantom Supply Module (model PM-1). A fixed microphone distance of 1.0 cm from the lips was maintained by an adjusted headset for each subject [23]. This distance was suggested by the manufacturer because the microphone is boom-style, directional, noise-canceling, which ensured that ambient room noise will not inflate amplitude values or interfere with pitch extraction at very low amplitudes [23].

Before recording the profile, the investigator demonstrated the procedures for a voice range profile. To help motivate subjects to perform maximally, subjects were instructed to use a minimum of three trials. The sound signal of each trial was captured through a condenser microphone and CSL, which was then displayed on the screen of the computer monitor. The displayed sound signals on the monitor were used as visual feedback to reinforce subjects to produce sound to an extreme level. Once the investigator and subjects were confident in the task, subjects began compiling data for the voice range profile.

Subjects were instructed to sustain the vowel /a/ for a minimum of 2 s for each semitone along the musical scale in the modal register and falsetto. For all subjects, testing was initiated near fundamental frequency at C4 (261.6 Hz) for female subjects, and C3 (130.8 Hz) for male subjects. Subjects were asked to move up the scale to maximal level and then to descend to the lowest level. At each target frequency, subjects produced softest and loudest voices to obtain the maximum intensity range. Vocal sound level was measured with an A-weighted frequency curve. All sound signals during measurements were captured through a condenser microphone and CSL with a Kay Phonetogram. These signals were then stored in a computer. The resultant frequencies were plotted on the x axis in semitones from A1 (55.0 Hz) to G6 (1,568.0 Hz), and the sound intensities were plotted on the y axis in decibel SPL from 50.0 to 125.0 to produce a voice range profile.

In order to compare voice range profiles across speakers, frequencies in Hertz were converted to number of semitones. Calculating the difference between the highest and the lowest frequency determined the maximum range of vowel frequency change (MRVFC) [24], which was then divided into 10% intervals. Measurements of intensity were calculated at each interval. The difference between the loudest voice and the softest voice for each 10% interval of MRVFC was determined as the intensity range in decibel SPL at that interval. The averaged intensity range for each 10% interval of MRVFC was regarded as the dynamic intensity range. The averaged loudest voice for each 10% interval of MRVFC for each subject was regarded as loud voice, and the averaged softest voice as soft voice. The highest frequency, the lowest frequency, MRVFC, loud voice, soft voice, and dynamic intensity range in the same subject group were averaged for statistical analysis.

Table 1. Means, standard deviations (SD), and independent t test of frequency and intensity variables in voice range profiles for female and male speakers

	Female (n = 20)		Male (n = 20)		t	p
	mean	SD	mean	SD		
Lowest frequency, st	28.60	2.20	18.60	1.70	16.16	0.000 ^a
Highest frequency, st	65.90	2.70	60.00	1.50	8.49	0.000 ^a
MRVFC, st	37.30	2.50	41.40	2.50	-5.18	0.000 ^a
Soft voice, dB	63.40	1.90	62.10	3.00	1.63	0.112
Loud voice, dB	101.40	2.90	100.60	3.40	0.79	0.434
Dynamic intensity range, dB	38.00	2.40	38.50	3.70	-0.50	0.622

st = Number of semitones.
^a p < 0.05.

Reliability

The first 10 subjects of the study were used to do test-retest procedures for the voice range profile. For all subjects the highest frequency, the lowest frequency, MRVFC, loud voice, soft voice, and dynamic intensity range were measured twice at 1-week intervals with the same procedures. The data of the two procedures for all measurements were collected and analyzed with intraclass correlation coefficient. Reliability of test-retest procedures of all frequency and intensity measurements was between 0.83 and 0.92.

Statistical Analysis

The independent t test was used to find the statistical significance of all frequency and intensity variables between female and male speakers in vocal range profiles. An alpha level of 0.05 was set in the test. Therefore, only statistical test results that have p levels of less than 0.05 were considered significant. All statistical analyses were performed using SPSS for Windows 12.

Results

Data on frequency and intensity in voice range profiles and statistical analysis with the independent t test for the female and male speakers are reported in table 1. In voice range profiles, the resulting independent t test showed that the lowest frequency and the highest frequency for the female speakers were significantly greater than those for the male speakers ($p < 0.05$). However, the MRVFC for the male speakers was significantly greater than that for the female speakers ($p < 0.05$). No significant difference was found in soft voice, loud voice, and dynamic intensity range in vocal range profiles between the female and male speakers.

Data on MRVFC of this study and studies of the nontonal languages under different conditions of tone, age, gender, larynx, and vocal training are reported in table 2. Data on dynamic intensity range of this study and studies of the nontonal languages under different conditions are reported in table 3.

Discussion

Comparison of Vocal Range Profiles between Female and Male Min Speakers

In this study, the lowest frequency and the highest frequency for female speakers were significantly greater than for male speakers, which was mainly due to vocal fold length and stiffness difference in the two genders [25]. The finding that male speakers exhibited a significantly greater MRVFC than female speakers was consistent with several authors' findings for American, Swedish, Dutch, and Belgian adults [10, 21, 24, 26]. However, the results contradicted other investigators' reports for American and Swedish adults [8, 9, 27–29]. In the present study, the fact that male speakers had a greater MRVFC may be associated with an inherently larger amplitude of vocal fold vibration of males coupled with larger subglottal pressure and spectral shaping, resulting in a better maximum vocal performance [30].

MRVFC: Comparison between Min and Nontonal Languages

Age. Comparing the data of the present study with those of other studies for nontonal languages, we found that in our study the MRVFC for young adult normal female speakers was smaller than that found by Brown et al. [8], and similar to that reported by Coleman et al. [27] for the nontonal language of American English. However, our MRVFC was greater than the value reported by Ptacek et al. [5], Hollien et al. [24], Linville [31], Britto and Doyle [28], Awan [7], Yin [32], and Sulter et al. [10] for speakers of American English and Dutch. On the other hand, our MRVFC for female Min speakers was greater than those found by Behrman et al. [33], Ohlsson and Lofqvist [26], Gramming and Akerlund [29], Heylen et al. [21], and Siupsinskiene [22] for speakers of American

Table 2. Summary of the present study and previous investigations on MRVFC (st) in voice range profiles

Investigators	Native language	Tonal/ nontonal language	Age years	Laryngeal condition	Singer/ nonsinger	MRVFC ^a , st	
						female	male
Present study	Min	tonal	21–29 F 21–27 M	normal	nonsinger	37.30 (2.50)	41.40 (2.50)
Ptacek et al. [5]	American English	nontonal	18–38 F 18–39 M	normal	nonsinger	32.80 (4.40)	34.50 (5.20)
Ptacek et al. [5]	American English	nontonal	66–93 F 68–89 M	normal	nonsinger	25.10 (7.90)	26.50 (6.30)
Hollien et al. [24]	American English	nontonal	18–36 F and M	normal	nonsinger	37.00 (5.30)	37.90 (5.00)
Colton [35]	American English	nontonal	18–25 M	normal	nonsinger	–	33.30 (–)
Coleman et al. [27]	American English	nontonal	20–39 F 21–34 M	normal	nonsinger	37.40 (–)	37.10 (–)
Linville [31]	American English	nontonal	25–35 F	normal	nonsinger	33.13 (3.43)	–
Linville [31]	American English	nontonal	45–55 F	normal	nonsinger	34.00 (3.22)	–
Linville [31]	American English	nontonal	70–80 F	normal	nonsinger	28.96 (4.13)	–
Britto and Doyle [28]	American English	nontonal	23.6 F 24.6 M	normal	nonsinger	36.70 (4.00)	30.90 (3.80)
Awan [7]	American English	nontonal	21.3 F and M	normal	nonsinger	27.45 (5.10) F and M	27.45 (5.10) F and M
Brown et al. [8], Morris et al. [9]	American English	nontonal	20–35 F and M	normal	nonsinger	38.00 (–)	36.60 (4.20)
Brown et al. [8], Morris et al. [9]	American English	nontonal	40–55 F and M	normal	nonsinger	39.00 (–)	36.90 (5.00)
Brown et al. [8], Morris et al. [9]	American English	nontonal	65–85 F >65 M	normal	nonsinger	33.00 (–)	29.70 (5.20)
Behrman et al. [33]	American English	nontonal	19–70 F and M	normal	nonsinger	30.30 (6.90) F and M	30.30 (6.90) F and M
Yin [32]	American English	nontonal	20–29 F	normal	nonsinger	32.20 (3.22)	–
Ohlsson and Lofqvist [26]	Swedish	nontonal	19–60 F and M	normal	nonsinger	33.0 (–)	36.00 (–)
Gramming and Akerlund [29]	Swedish	nontonal	21–69 F 21–81 M	normal	nonsinger	29.90 (–)	28.30 (–)
Sulter et al. [10]	Dutch	nontonal	17–44 F 17–35 M	normal	nonsinger	35.16 (4.62)	38.28 (3.78)
Heylen et al. [21]	Belgian	nontonal	22–51 F 22–54 M	normal	nonsinger	31.30 (0.70)	33.30 (1.00)
Teles-Magalhaes et al. [34]	Brazilian Portuguese	nontonal	60–84 F	normal	nonsinger	19.70 (3.09)	–
Siupsinskiene [22]	Lithuanian	nontonal	18–67 F and M	normal	nonsinger	29.60 (–)	34.10 (–)
Behrman et al. [33]	American English	nontonal	11–78 F 24–85 M	organic vocal fold pathology	nonsinger	13.50 (5.00) F and M	13.50 (5.00) F and M
Gramming [13]	Swedish	nontonal	25–57 F 21–57 M	nonorganic dysphonia	nonsinger	27.80 (–)	25.40 (–)
Heylen et al. [21]	Belgian	nontonal	–	vocal nodules	nonsinger	23.80 (1.20)	19.80 (2.40)
Colton [35]	American English	nontonal	18–25 M	normal	singer	–	34.90 (–)
Awan [7]	American English	nontonal	22.3 F and M	normal	singer	34.40 (3.19) F and M	34.40 (3.19) F and M
Brown et al. [8], Morris et al. [9]	American English	nontonal	20–35 F 25–35 M	normal	singer	45.00 (–) sopranos 44.00 (–) altos	40.20 (4.20) tenor 43.60 (5.60) bass/baritone
Sulter et al. [10]	Dutch	nontonal	18–59 F 21–75 M	normal	singer	39.84 (4.79)	37.92 (5.95)
Siupsinskiene [22]	Lithuanian	nontonal	18–70 F and M	normal	singer	34.40 (–)	37.70 (–)

^a Mean values and SD (in parentheses) are given. st = Semitones.

Table 3. Summary of the present study and previous investigations on dynamic intensity range (mean, SD) in voice range profiles

Investigators	Native language	Tonal/ nontonal language	Age years	Laryngeal condition	Singer/ nonsinger	Dynamic intensity range, dB	
						female	male
Present study	Min	tonal	21–29 F 21–27 M	normal	nonsinger	38.00 (2.40)	38.50 (3.70)
Awan [7]	American English	nontonal	21.3 F and M	normal	nonsinger	9.45 (–) F and M	9.45 (–) F and M
Behrman et al. [33]	American English	nontonal	19–70 F and M	normal	nonsinger	28.50 (–) F and M	28.50 (–) F and M
Yin [32]	American English	nontonal	20–29 F	normal	nonsinger	18.19 (3.94)	–
Sulter et al. [10]	Dutch	nontonal	17–44 F 17–35 M	normal	nonsinger	27.47 (–)	29.65 (–)
Teles-Magalhaes et al. [34]	Brazilian Portuguese	nontonal	60–84 F	normal	nonsinger	22.65(–)	–
Behrman et al. [33]	American English	nontonal	11–78 F 24–85 M	organic vocal fold pathology	nonsinger	8.30 (–) F and M	8.30 (–) F and M
Sulter et al. [10]	Dutch	nontonal	18–59 F 21–75 M	normal	singer	31.37 (–)	32.13 (–)

English, Swedish, Belgian, and Lithuanian. It was also greater than Linville's [31] value reported for American English-speaking middle-aged female adults, and the values obtained by Ptacek et al. [5], Linville [31], Brown et al. [8], and Teles-Magalhaes et al. [34] for advanced adult female speakers of American English and Brazilian Portuguese. However, the MRVFC value in our study was smaller than that found by Brown et al. [8] for American English-speaking middle-aged adults. For male speakers, the MRVFC of Min was greater than that of American English and Dutch normal young adults [5, 7, 9, 10, 24, 27, 28, 35]. Also, the MRVFC values for Min speakers were greater than those of normal middle-aged adult speakers of American English, average adult speakers of American English, Swedish, Belgian, and Lithuanian, and advanced adult speakers of American English [5, 9, 21, 22, 26, 29, 33].

Laryngeal Conditions. Comparing the normal data in the present study with those of voice-disordered speakers of nontonal languages, we found that our MRVFC for female and male speakers was much greater than those found by Behrman et al. [33] and Heylen et al. [21] for American English and Belgian speakers with organic laryngeal pathology. Also, the MRVFC for speakers in the present study was much greater than that found by Gramming [13] for non-organic dysphonic speakers of Swedish.

Vocal Training. Comparison of our results with those in other studies for speakers of nontonal languages who had experience of vocal training showed that our MRVFC for female speakers was smaller than those found by

Brown et al. [8] and Sulter et al. [10] for American English and Dutch female singers. However, it was greater than the values reported by Awan [7] and Siupsinskiene [22] for American English and Lithuanian female singers. For male speakers, the MRVFC in our study was smaller than that found by Morris et al. [9] for American English bass and baritone singers, but greater than that for the American English tenors studied by Morris et al. [9] and that for the American English, Dutch, and Lithuanian singers reported by Colton [35], Awan [7], Sulter et al. [10], and Siupsinskiene [22], respectively.

Dynamic Intensity Range: Comparison with Nontonal Languages

Age. Comparison between our data and those in other studies for young adult male and female normal speakers of nontonal languages revealed that in this study, the dynamic intensity ranges for female and male speakers were greater than those found by Awan [7], Yin [32] and Sulter et al. [10] for American English and Dutch speakers of the respective genders. Also, our speakers' dynamic intensity range was greater than that found by Behrman et al. [33] for average adult American English speakers and that observed by Teles-Magalhaes et al. [34] for Brazilian Portuguese advanced female adults.

Laryngeal Condition and Vocal Training. In our study, the dynamic intensity range for female and male speakers was much greater than that found by Behrman et al. [33] for American English speakers with organic laryngeal pathology and also that for Dutch singers [10].

Explanations for the Differences in Vocal Range Profiles between Min and Nontonal Languages

The MRVFC and dynamic intensity range for Min speakers of both sexes in this study were greater than those for normal speakers of nontonal languages of all age groups (young, middle-aged, and advanced adults). Both parameters were also greater than those for all organic and nonorganic voice-disordered speakers of nontonal languages. Moreover, the data showed a greater MRVFC and dynamic intensity range for Min speakers than for most singers of a nontonal language. The differences in MRVFC and dynamic intensity range between the tonal language investigated in our study and the nontonal languages of other studies may be explained by the different speaking frequency and speaking intensity ranges of Min and nontonal languages. In Chen's [20] study, the author reported that the speaking frequency range for female Min speakers was 15.40 st, and for male speakers 12.50 st, whereas the speaking intensity range for female Min speakers was 31.90 dB, and for male speakers 30.40 dB. The speaking frequency range of female Min speakers was 1.40–9.17 st, and that of male speakers 2.75–7.0 st greater than that of most American English speakers of the same gender. The speaking intensity range of female Min speakers was 27.95 dB and that of male speakers was 25.85 dB greater in comparison with American English speakers [20]. The expanded speaking frequency and intensity ranges for Min speakers may have a similar effect as vocal training, which enhances MRVFC and dynamic intensity range in maximum vocal performance.

If expanded speaking frequency and speaking intensity ranges in Min dialect are analogous to vocal training in singers and voice therapy in voice-disordered patients, the control mechanisms of vocal training and voice therapy can be explained. Titze and Sundberg [36] demonstrated that speakers with singing training used a smaller phonation threshold pressure during phonation than the group with no singing training. Stemple et al. [3] and Sabol et al. [37] found that normal speakers showed a significant increase in phonation volume, flow rate, maximum phonation time, and frequency range after vocal function exercise. Bassiouny [2] further reported that voice-disordered patients had decreased phonatory gaps, and increased vocal fold vibration amplitude and mucosal wave, glottal efficiency, and dynamic intensity range after the accent method of voice therapy. Dromey et al. [38] and Ramig et al. [39] found that after Lee Silverman voice treatment, patients with Parkinson's disease had increased vocal loudness, phonatory stability, and fundamental frequency variability by increasing subglottal air

pressure, vocal fold adduction, and maximum flow declination rate. Furthermore, Elliot et al. [40] and Laukkanen et al. [41] documented that vocal economy was improved by decreasing muscular activity in the laryngeal muscles and lowering laryngeal position in vowel production after vocal training. Schneider et al. [42] suggested that constant overload training on respiratory and laryngeal muscles can change control mechanisms by enhancing muscular fitness resulting in better vocal function.

It follows, then, that the daily conversation with large frequency and intensity changes as used by Min speakers can be considered a vocal training which may increase respiratory support, vocal fold adduction, vocal fold tension and vibration, and laryngeal muscle activation and synergy. These physiological effects of vocal training of Min can therefore be considered to enhance respiratory and laryngeal muscular strength, endurance, and flexibility, resulting in an increased maximum vocal performance on frequency and intensity for Min speakers when compared to nontonal language speakers.

Conclusion

Because the MRVFC and dynamic intensity range for Min speakers were greater than those for nontonal language speakers, use of data obtained from nontonal language speakers may underestimate vocal function and therefore lead to inappropriate treatment. Since there are no existing data on voice range profiles in Taiwan, the data obtained in this study can be used as an assessment tool of vocal function for young adult Min speakers. These data can also be used to monitor voice therapy and phonosurgery effects. Because the difference in vocal ranges exhibited by Min speakers compared to nontonal language speakers was evident, it underscored the need for normal databases for different dialects.

Further study needs to include aerodynamic measurements such as airflow rate and intraoral pressure for evaluation of respiratory control and phonation efforts. These measurements can help us understand the physiological mechanisms in Min dialect. In addition, comparison of frequency and intensity data in voice range profiles across different age groups for Min speakers in Taiwan and speakers of nontonal languages could provide more reliable data for assessment and treatment of geriatric, middle-aged, and preadolescent patients who have voice disorders. Studies of other tonal languages are also warranted.

References

- 1 Titze IR: Principles of Voice Production. Iowa City, National Center for Voice and Speech, 2000.
- 2 Bassiouny S: Efficacy of the accent method of voice therapy. *Folia Phoniatr Logop* 1998; 50:146–164.
- 3 Stemple JC, Lee L, D'Amico B, Pickup B: Efficacy of vocal function exercises as a method of improving voice production. *J Voice* 1994;8:271–278.
- 4 Kent RD, Kent JF, Rosenbek JC: Maximum performance tests of speech production. *J Speech Hear Disord* 1987;52:367–387.
- 5 Ptacek P, Sander EK, Malone WH, Jackson CCR: Phonatory and related changes with advanced age. *J Speech Hear Res* 1966;9:353–360.
- 6 Akerlund L, Gramming P, Sundberg J: Phonetogram and averages of sound pressure levels and fundamental frequencies of speech: comparison between female singers and nonsingers. *J Voice* 1992;6:55–63.
- 7 Awan SN: Phonetographic profiles and F₀-SPL characteristics of untrained versus trained vocal groups. *J Voice* 1991;5:41–50.
- 8 Brown WS, Morris RJ, Hicks DM, Howell E: Phonational profiles of female professional singers and nonsingers. *J Voice* 1993;7:219–226.
- 9 Morris RJ, Brown WS, Hicks DM, Howell E: Phonational profiles of male trained singers and nonsingers. *J Voice* 1995;9:142–148.
- 10 Sulter AM, Schutte HK, Miller DG: Differences in phonetogram features between male and female subjects with and without vocal training. *J Voice* 1995;9:363–377.
- 11 Neuschaefer-Rube C, Sram F, Klajman S: Three-dimensional phonetographic assessment of voice performance in professional and non-professional speakers. *Folia Phoniatr Logop* 1997;49:96–104.
- 12 Akerlund L: Averages of sound pressure levels and mean fundamental frequencies of speech in relation to phonetograms: comparison of nonorganic dysphonia patients before and after therapy. *Acta Otolaryngol* 1993;113:102–108.
- 13 Gramming P: Non-organic dysphonia: phonetograms for pathological voices before and after therapy. *Scand J Logoped Phoniatr* 1988;1:3–16.
- 14 Awan SN: Superimposition of speaking voice characteristics and phonetograms in untrained and trained vocal groups. *J Voice* 1993;7:30–37.
- 15 Hwang Shiuan-Fan: Language, Society, and Ethnic Consciousness: A Sociolinguistic Study in Taiwan. Taipei, Wen Ho Publisher, 1995.
- 16 Ting Pang-Hsin: The Source of Dialects in Taiwan. Taipei, Shyue Sheng Publisher, 1979.
- 17 Huang Wei-Ren: The Study of Tones in Min Dialect in Taiwan. Taipei, Tzu Li Wan Pao Wen Hua Publisher, 1990.
- 18 Chen GT: A Comparative Study of Pitch Range of Native Speakers of Midwestern English and Mandarin Chinese: An Acoustic Study; PhD diss University of Wisconsin-Madison, Madison, 1972.
- 19 Titze IR: Regulation of vocal power and efficiency by subglottal pressure and glottal width; in Fujimura O (ed): *Vocal Fold Physiology: Voice Production, Mechanisms, and Functions*. New York, Raven, 1988.
- 20 Chen SH: The effects of tones on speaking frequency and intensity ranges in Mandarin and Min dialects. *J Acoust Soc Am* 2005;117:3225–3230.
- 21 Heylen L, Wuyts FL, Mertens F, De Bodt M, Pattyn J, Van de Heyning PH: Comparison of the results of the frequency and the intensity data of the BSGVD with phonetogram characteristics. *Acta Otorhinolaryngol Belg* 1996;50:353–360.
- 22 Siupsinskiene N: Quantitative analysis of professionally trained versus untrained voices. *Medicina* 2003;39:36–46.
- 23 Kay Elemetrics Corporation: Voice Range Profile Model 4326. Lincoln Park, Kay Elemetrics, 1994.
- 24 Hollien H, Dew D, Philips P: Phonational frequency ranges of adults. *J Speech Hear Res* 1971;14:755–760.
- 25 Titze IR: Physiologic and acoustic differences between male and female voices. *J Acoust Soc Am* 1989;85:1699–1707.
- 26 Ohlsson AC, Lofqvist A: Phonetograms of normal and pathological voices. *Working Papers Logoped Phoniatr* (Lund University) 1986;3:94–106.
- 27 Coleman RF, Mabis JH, Hinson JK: Fundamental frequency-sound pressure level profiles of adult male and female voices. *J Speech Hear Res* 1977;20:197–204.
- 28 Britto AI, Doyle PC: A comparison of habitual and derived optimal voice fundamental frequency values in normal young adult speakers. *J Speech Hear Disord* 1990;55:476–484.
- 29 Gramming P, Akerlund L: Non-organic dysphonia II. Phonetograms for normal and pathological voices. *Acta Otolaryngol* (Stockh) 1988;106:468–476.
- 30 Titze IR: Acoustic interpretation of the voice range profile. *J Speech Hear Res* 1992;35:21–34.
- 31 Linville SE: Maximum phonational frequency range capabilities of women's voices with advancing age. *Folia Phoniatr* 1987;39:297–301.
- 32 Yin SJ: Vocal Range Profiles of Native Taiwanese-Mandarin and American-English Speakers; Master's thesis University of Wisconsin-Eau Claire, Eau Claire, 2001.
- 33 Behrman A, Agresti CJ, Blumstein E, Sharma G: Meaningful features of voice range profiles from patients with organic vocal fold pathology: a preliminary study. *J Voice* 1996; 10:269–283.
- 34 Teles-Magalhaes LC, Pegoraro-Krook MI, Pegoraro R: Study of the elderly females' voice by phonetography. *J Voice* 2000;14:310–321.
- 35 Colton RH: Phonational range in the modal and falsetto registers. *J Speech Hear Res* 1972;15:708–713.
- 36 Titze IR, Sundberg J: Vocal intensity in speakers and singers. *J Acoust Soc Am* 1992; 91:2936–2946.
- 37 Sabol JW, Lee L, Stemple JC: The value of vocal function exercises in the practice regimen of singers. *J Voice* 1995;9:27–36.
- 38 Dromey C, Ramig LO, Johnson AB: Phonatory and articulatory changes associated with increased vocal intensity in Parkinson disease: a case study. *J Speech Hear Res* 1995; 38:751–764.
- 39 Ramig LO, Sapir S, Countryman S, Pawlas AA, O'Brien C, Hoehn M, Thompson LL: Intensive voice treatment (LSVT) for patients with Parkinson's disease: a 2 year follow-up. *J Neurol Neurosurg Psychiatry* 2001;71:493–498.
- 40 Elliot N, Sundberg J, Gramming P: Physiological aspects of a vocal exercise. *J Voice* 1997; 11:171–177.
- 41 Laukkanen A, Lindholm P, Vilkman E, Haataja K, Alku P: A physiological and acoustic study on voiced bilabial fricative /β:/ as a vocal exercise. *J Voice* 1996;10:67–77.
- 42 Schneider CM, Dennehy CA, Saxon KG: Exercise physiology principles applied to vocal performance: the improvement of postural alignment. *J Voice* 1997;3:332–337.